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8725 John J. Kingman Road, MS 6201
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TECHNICAL REPORT

Cancer Mortality in Populations in Kazakhstan Subjected to Irradiation from Nuclear Weapons Testing in China

May 2008

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B.I. Gusev et al.

Prepared by:
ITT Corporation
Advanced Engineering & Sciences
2560 Huntington Avenue
Alexandria, VA 22303-1410

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B.I. Gusev
N.N. Kurakina
A.Kh. Sekerbaev

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The radiation situation which occurred due to the nuclear weapons testing in China from 1964 to 1981 has been reconstructed. The ranges of external and internal doses have been estimated for the populations of the Makanchy, Urdzhar and Taskesken Districts of Semipalatinsk Province; these doses were formed as a result of eleven surface nuclear explosions conducted from 1967 to 1981. An analysis was done of the dynamics of cancer mortality of the population in the districts monitored from 1949 to 1997; the relative and attributive risks of cancer mortality of the population were calculated, according to both total malignant neoplasms and to individual primary sites.

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CONVERSION TABLE

Conversion factors for U.S. Customary to metric (SI units of measurement)

MULTIPLY TO GET	BY BY	TO GET DIVIDE
angstrom	1.000 000 x E-10	meters (m)
atmosphere	1.012 25 x E +2	kilo pascal (kPa)
bar	1.000 000 x E + 2	kilo pascal (kPa)
barn	1.000 x E – 28	meter^2 (m^2)
British thermal unit (thermochemical)	1.054 350 x E + 3	joule (J)
calorie (thermochemical)	4.184 000	joule (J)
cal (thermochemical)/cm^2	4.184 000 x E-2	mega joule/m^2 (MJ/m^2)
curie	3.700 000 x E + 1	giga becquerel (GBq)*
degree (angle)	1.745 329 x E – 2	radian (rad)
degree (Fahrenheit)	Tk = (t +459.69)/1.8	degree kelvin (K)
electron volt	1.602 19 x E – 19	joule (J)
erg	1.000 000 x E – 7	joule (J)
erg/sec	1.000 000 x E – 7	watt (W)
foot	3.048 000 x E-1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (U.S. liquid)	3.785 412 x E – 3	meter^3 (m^3)
inch	2.540 000 x E -2	meter (m)
jerk	1.000 000 x E + 9	joule (J)
joule/kilogram (J/kg) (absorbed dose)	1.000 000	Gray (Gy)**
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 x E + 3	newton (N)
kip/inch^2 (ksi)	6.894 757 x E +3	kilo pascal (kPa)
ktap	1.000 000 x E +2	newton-second/m^2 (N-s/m^2)
micron	1.000 000 x E – 6	meter (m)
mil	2.540 000 x E – 5	meter (m)
mile (international)	1.609 344 x E + 3	meter (m)
ounce	2.834 952 x E – 2	kilogram (kg)
pound-force (lbf avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 x E – 1	newton-meter (N*m)
pound-force/inch	1.751 268 x E + 2	newton-meter (N/m)
pound-force/foot^2	4.788 026 x E – 2	kilo pascal (kPa)
pound-force/inch^2 (psi)	6.894 757	kilo pascal (kPa)
pound-mass-foot^2 (moment of inertia)	4.214 011 x E – 2	kilogram-meter^2 (kg*m^2)
pound-mass/foot^3	1.601 846 x E + 1	kilogram/m^3 (kg/m^3)
rad (radiation absorbed dose)	1.000 000 x E – 2	Gray (Gy) **
rem (roentgen equivalent man)		Sievert (Sv) ***
roentgen	2.579 760 x E – 4	coulomb/kilogram (C/kg)
shake	1.000 000 x E – 8	second (s)
Slug	1.459 390 x E + 1	kilogram (kg)
Torr (mm Hg, 0 degrees C)	1.333 22 x E – 1	kilo pascal (kPa)

* *The Becquerel (Bq) is the SI unit of radioactivity: 1 Bq = 1 event/s.*

** *The Gray (Gy) is the SI unit of absorbed radiation.*

*** *The Sievert (Sv) is the SI unit of dose equivalent.*

ABSTRACT

The radiation situation which occurred due to the nuclear weapons testing in China from 1964 to 1981 has been reconstructed. The ranges of external and internal doses have been estimated for the populations of the Makanchy, Urdzhar and Taskesken Districts of Semipalatinsk Province; these doses were formed as a result of eleven surface nuclear explosions conducted from 1967 to 1981. An analysis was done of the dynamics of cancer mortality of the population in the districts monitored from 1949 to 1997; the relative and attributive risks of cancer mortality of the population were calculated, according to both total malignant neoplasms and to individual primary sites.

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TABLE OF CONTENTS

LIST OF FIGURES

Figures **Page**

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

CANCER MORTALITY IN POPULATIONS IN KAZAKHSTAN SUBJECTED TO IRRADIATION FROM NUCLEAR WEAPONS TESTING IN CHINA

1.0 INTRODUCTION

From 1964 to 1981, 24 surface and atmospheric nuclear explosions were conducted in China at the Lop Nor Test Site. As a result of these tests, freshly produced fission products appeared in objects in the environment and in milk in the population points of the Makanchy, Urdzhar and Taskesken Districts of Semipalatinsk Province, located 900-1,100 km away from the Chinese Test Site. The contamination levels varied within very wide ranges. The radionuclides, in transferring from objects in the environment into food products, led to biological effects on the human body. In 1984 the medical statistics authorities began to record a significant rise in fatal cases of cancer among the populations of the above-noted districts; this rise significantly exceeded the dynamics of cancer distribution in preceding years. Especially significant increases in fatal cancer cases were registered in such primary sites as breast and lung cancer.

After the UK, USA, and USSR signed a treaty banning nuclear weapons tests in the atmosphere, space, and underwater, the principal contribution to the activity of the near-surface atmosphere and to fallout was made by isotopes of cerium, ruthenium and zirconium-95 with niobium-95. The long-lived cesium-137 and strontium-90 isotopes were vented into the stratosphere during nuclear testing, which stopped at the end of 1962. On the territory of the USSR, for the period of 1963 to 1981, the following have been detected, in the atmosphere and in fallout: the isotopes ruthenium-103 and -106, cerium-141 and -144, and zirconium-95 with niobium-95. The principal source of entry of these isotopes into the surface air, clearly, were the surface and atmospheric tests conducted in the People's Republic of China (PRC). Atmospheric tests in France during this period were conducted in the southern hemisphere, and the annual movement of their fission products to the northern hemisphere was minimal. The underground nuclear device tests conducted in the USSR and the USA could not significantly increase the content of the above-noted isotopes, since even during an underground explosion with ejection of ground, a large portion of the activity (60-70%) remains in the close-in zone (100-200 km). During such underground explosions, the radioactive cloud does not rise into the higher layers of the atmosphere; the radioactive materials do not transfer to the stratosphere, and therefore, we do not see global contamination of the biosphere.

The purpose of this work was to estimate the effective radiation doses to the population of the southern portions of the Semipalatinsk Province as a result of nuclear weapons tests in China, and to establish a link in the excess cases of malignant cancer with irradiation of the population.

2.0 MATERIALS AND METHODS OF INVESTIGATIONS

2.1 TEST CHRONOLOGY AND PARAMETERS

The date, yield, type, and altitude of these 24 explosions are given in Table 1.

Table 1. Chronology and parameters of nuclear tests conducted at the Chinese test site.

Test Number	Date of Explosion	Yield (TNT Equiv.)	Type of Detonation	Altitude	Notes
1	10/16/64	Up to 5 kT	Nuclear	~30 m	From tower
2	5/14/65	Up to 25 kT	Nuclear	150-350 m	From aircraft
3	5/9/66	~100 kT	Thermonuclear	1-1.5 km	From aircraft
4	10/27/66	Up to 5 kT	Nuclear	150-350 m	From missile
5	12/28/66	0.3 MT (~100 kT)*	Thermonuclear	100-150 m	From tower
6	6/17/67	0.4 MT (~2 MT)*	Thermonuclear	100-150 m	From tower
7	12/24/67	Up to 5 kT	Nuclear	30 m	From tower
8	12/28/68	2-3 MT	Thermonuclear	6-8 km	Atmospheric
9	9/29/69	2-3 MT	Thermonuclear	6-8 km	Atmospheric
10	10/14/70	2-3 MT	Thermonuclear	6-8 km	Atmospheric
11	11/18/71	10 kT	Nuclear	150-350 m	From aircraft
12	1/7/72	20 kT	Nuclear	100-150 m	From tower
13	3/18/72	20-200 kT	Thermonuclear	1-1.5 km	From aircraft
14	6/27/73	2-3 MT	Thermonuclear	1-1.5 km	From aircraft
15	6/17/74	(0.2-1 MT) 3 MT*	Thermonuclear	1-1.5 km	From aircraft
16	1/23/76	10 kT	Nuclear	Underground	With ejection
17	9/26/76	20 kT	Nuclear	30 m	From tower
18	10/17/76	--	Nuclear	Underground	
19	11/17/76	4 MT (2 MT)*	Thermonuclear	1-1.5 km	From aircraft
20	9/17/77	20 kT (20-200 kT)*	Nuclear	30 m	From tower
21	3/15/78	20 kT	Nuclear	30 m	From tower
22	12/14/78	20 kT	Nuclear	30 m	From tower
23	10/16/80	(0.25-1 MT) 1 MT*	Nuclear	8 km	Atmospheric
24**	11/12/81	20 kT	Nuclear	30 m	From tower

* *Data from different sources vary—Ed.*

** *This test not included in other references.*

In eleven cases, taking the wind into consideration, the Makanchy, Urdzhar and Taskesken districts were contaminated by fission products. The radiation situation was reconstructed based on archival materials and measurements of the radioactivity in objects found in the environment and in locally produced food products. The internal radiation doses were calculated based on the explosion parameters with regard to the time they were conducted and according to the results of measuring of milk samples taken in specific population points.

2.2 AREAS INVESTIGATED

To estimate the radiation situation on the territories of the districts under study, we plotted two routes from the southern border of the Semipalatinsk Province along the largest population points: Bakhty to Taskesken and Karabuta to Alekseevka. Figure 1 presents a map showing the locations of the Lop Nor and Semipalatinsk Test Sites as well as the three population points of Makanchy, Urdzhar, and Taskesken.

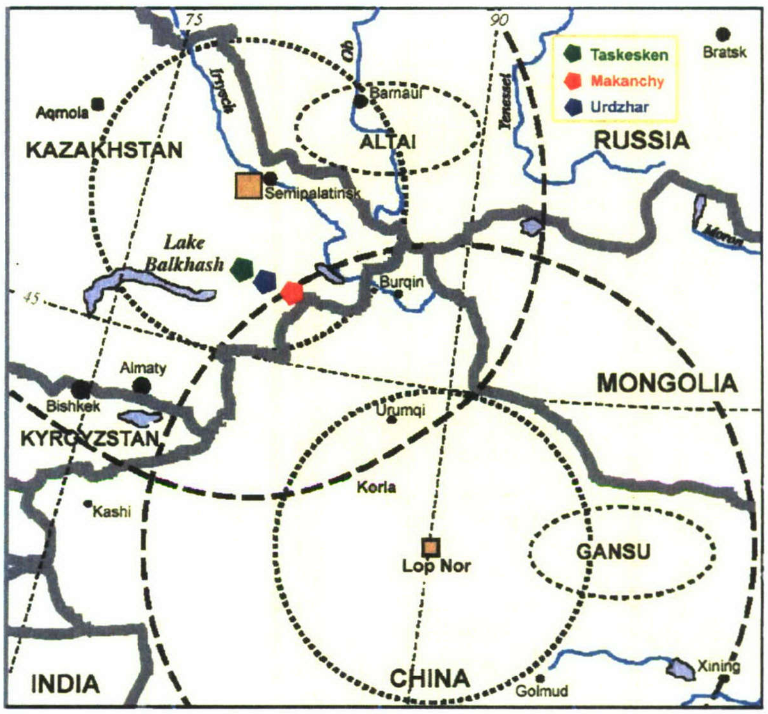

Figure 1. Map of Test Sites and Villages.

The population points sampled and the volume of analyzed samples of soil, vegetation and milk, both from archival materials and from sampling in 1998, is shown in Table 2.

Table 2. Location, type, and number of samples processed.

Population Point	Archival Data			Sampling Performed in 1998				
	Soil	Vegetation	Milk	Soil	Hay	Meat	Milk	Bone
Makanchy District (total)				46	30	30	30	30
Bakhty				13	5	5	5	5
Makanchy	56	45	45	13	5	5	5	5
Karatal				5	5	5	5	5
Karabuta				5	5	5	5	5
Blagodarnoe				5	5	5	5	5
Kirovka				5	5	5	5	5
Urdzhar District (total)				38	30	30	30	30
Urdzhar	56	45	45	13	5	5	5	5
Aksakovka				5	5	5	5	5
Irinovka				5	5	5	5	5
Besterek				5	5	5	5	5
Novoandreevka				5	5	5	5	5
Alekseevka				5	5	5	5	5
Taskesken District (total)				38	30	30	30	30
Laibulak				5	5	5	5	5
Predgornoe				5	5	5	5	5
Tekebulak				5	5	5	5	5
Taskesken	56	45	45	13	5	5	5	5
Zhanama				5	5	5	5	5

The exposed population represents individuals living in the Makanchy, Urdzhar and Taskesken districts. The comparison group included the population from the Kokpekty district of the Semipalatinsk Province who, for all practical purposes, were not subjected to radiation. The ethnic, age, and gender composition of the exposed and control groups were similar, as shown in Table 3.

Table 3. Dynamics of age group distribution of the population of Makanchy, Urdzhar, Taskesken and Kokpekty Districts (thousands).

Age group, years	Makanchy			Urdzhar, Taskesken			Kokpekty		
	1949	1963	1996	1949	1963	1996	1949	1963	1996
0-19	9.0	13.4	17.8	16.9	23.7	39.1	9.0	12.8	14.4
20-29	2.8	4.2	5.5	5.3	7.4	12.1	2.8	3.9	4.4
30-39	3.0	4.4	5.9	5.6	7.9	13.0	3.0	4.27	4.8
40-49	2.2	3.3	4.3	4.1	5.8	9.6	2.2	3.1	3.5
50-59	2.0	3.0	4.0	3.7	5.2	8.7	2.0	2.8	3.2
60 and older	1.0	1.5	2.0	1.9	2.6	4.3	1.0	1.4	1.6

The dynamics of fatal cancer cases among the populations of the Makanchy, Urdzhar and Taskesken districts were analyzed for the 1949 to 1996 time period. The distribution levels of fatal cancer cases before 1964 were calculated for the entire population in the study districts, and since 1994 for the radiation risk group only, without accounting for the numbers of migrants.

2.2.1 SAMPLING METHODS

a) Soil Samples.

The locations to take soil samples in a population point were selected according to the results of dosimeter investigations using the DRG-01-T dosimeter. A very important criterion was the lack of visible traces of agricultural activity by man (plowing the earth, construction, waste dumps). In the soil sampling locations, the vegetative cover is removed from the ground as are large and sharp stones. After taking the dose rate measurements in the open, a soil sample was taken. For consistency, a sampling shovel was used with dimensions 100 x 100 x 10 mm. The weight of each sample was at least 3 kg. The sample was taken by digging a small pit.

From the windward side, a trench was dug, 60 x 150 cm. Its depth was determined from the employed depth of the small pit excavation plus a little more (for a pit 100-cm deep, a 110-cm deep trench was dug). Having completed the preparatory work, the actual soil sampling took place. It began at the upper layer at a selected sampling interval.

Each sample was packed in an individually prepared and marked package. In this case, the sampling interval was every 5 cm down to the 10 cm layer, and up to the 100 cm layer, it was every 10 cm. Each sample weighed at least 3 kg.

b) Vegetation Samples.

The following vegetation samples were taken: grass growing near the soil sampling point, and hay from stacks located on the territory of the population point. The mass of the cut grass was 1.0 to 1.5 kg, and the hay, 0.5 kg.

c) Samples of Milk and Meat.

Samples of milk and meat were acquired in the local populace in those population points in the following amounts: milk- 6 l; meat- 6 kg per sample.

2.2.2 SAMPLE PREPARATION METHODOLOGY

Upon arrival at the laboratory, the soil samples were divided into four sections and dried at a temperature of 60 to 80 degrees Centigrade. Foreign bodies and remaining vegetation were removed. The samples were sifted through a 3.25 mm mesh sieve. For the gamma spectrometer measurements, the samples were packed in Marinelli containers. The mass of the samples was 1.8 to 2.5 kg. For radiochemical analysis, soil samples weighing 80-100 g were incinerated at a temperature of 400-500 degrees.

The vegetation samples were first dried at 40-50 degrees for 20 hours to an air-dried state, and foreign admixtures were cleaned out. This was followed by two stages of incineration at 400-450 degrees. The first stage was in stainless steel trays, and the second (with less volume of ash) in ceramic cups. During the incineration process, the sample was ground several times, and several drops of concentrated nitric acid were added. The obtained ash was sifted through a 1 mm mesh sieve; small pebbles were removed; and the weight restored by adding the air-dried sample. For alpha spectrometry, the ash was placed in plastic petri dishes. After measuring the sample, it was transferred for radiochemical analysis.

The milk samples were dried and incinerated. Tendons and fat were removed from the meat samples, then dried and incinerated. The bone samples were carefully removed from the muscles and ligaments, dried and incinerated. During the incineration process, the bones were ground in a mortar and sprinkled with a small quantity of concentrated nitric acid. The meat, milk and bone samples were packaged for measurements just like the vegetation samples.

2.3 RADIATION SURVEY

To conduct the research to study the radiation situation in population points of the Semipalatinsk Province, a gamma survey was conducted of the territory by measuring the exposure dose rates in the locale. For these purposes, a DRG-01-T dosimeter was used. The level of migration to depth of the radioactive trace was determined at the sampling points. To do this, every 5 cm, the surface contamination of the soil was measured by determining the density of the alpha and the beta particle flux. An MKS-01R-01 radiometer with removable sensors was used. When measuring the alpha particles, a BDKA-01R detection block was used. In each spot, 10 measurements were taken, each for 100 seconds. When measuring the beta particles, a BDKB-01R detection block was used; it has a cover filter which permits measurement of the beta particle flux in the presence of a gamma radiation background. Then when the cover was closed, the gamma radiation was measured; with it open, the gamma plus beta radiation was measured. The beta radiation was calculated according to the difference between these two values. In each point, 10 measurements were taken, for 10 seconds each.

2.4 SAMPLE ACTIVITY MEASUREMENT

The total beta activity of the samples was determined using type B-2 beta radiometers with MST-17 or SBT-10 face counters. Until 1973, the beta radiometers were calibrated using the equilibrium state Sr-90 + Y-90 standard. The average energy of the soil samples was not considered, and the average energy of the samples may differ from the average energy of this calibration standard. The data for total beta activity in the samples should be considered relative to each other, not the standard, and the results decreased or increased accordingly. In the subsequent period, the beta radionuclides were calibrated by a set of radionuclides (carbon-14, thallium-204, potassium-40, strontium-90 + yttrium-90, and yttrium-90) with an average energy range of 0.05 to 0.9 MeV. The average energy of the measured samples was determined experimentally using the absorbing aluminum screens method. The soil samples were measured in aluminum supports (targets) 32 mm in diameter and 6 mm high. The activity of the samples was calculated according to the usual formula. The average relative error of measuring the soil samples at a count of 2-7 pulses/minute was 30-80%.

The radionuclide composition of the environmental samples (soil and vegetation) and milk was determined on scintillating gammaspectrometer devices, the detectors of which were scint-blocks with crystals of NaI (Tl), measuring 63x63 and a resolution for cesium-137 no less than 10% with type AI-128-3 and AI-256-6 analyzers. See selected examples in Appendix C.

The spectrometer energy was calibrated and the effectiveness curve for recording gamma quanta by the peak total absorption was drawn with the help of a set of OSGI reference emitters on 10 energy lines (for yttrium-88: 1836 and 898 keV; cobalt-60: 1332 and 1173 keV; sodium-22: 1275 and 511 keV; zinc-65: 1115 keV; manganese-54: 834 keV; cesium-137: 661 keV; tin-113: 391 keV; cerium-139: 166 keV; cobalt-57: 122 keV, americium-241: 59.5 keV). To identify the radionuclides, we took repeated measurements of the samples. In our calculation formulas to determine the specific activity of the gamma-emitting radionuclides, in addition to the quanta output, we included the effectiveness values of the gamma spectrometer based on the recorded gamma-quanta, the correction for the configuration of measured sample and the mass of the measured sample. Since 1991, to determine the samples' radionuclide content, we used two units to take our measurements, including the following:

1. DGDK-50B-3 and DGDK-63-C germanium diffusive-drift detectors protected by 100 mm of lead;
2. AI-1024-95-17m multi-channel amplitudinal pulse analyzers;
3. ES-1841-11, IBM PC personal computers;
4. BaltiSpektr 3.02 and PPD-93 programs for processing gamma spectra.

The measurements are taken in "real time" at a 3.5-5.5 hour interval. The sensitivity of the method used for individual lines follows for the geometry of the Marinelli containers (soil samples):

For energy 186.1 keV: 0.301 ± 0.136 Bq/kg;
For energy 661.662 keV: 0.257 ± 0.249 Bq/kg;
For energy 1460.75 keV: 20.156 ± 6.047 Bq/kg.

For the geometry of the petri dishes (samples of vegetation, meat, milk, and bones):

For enrergy 186.1 keV: 0.021 ± 0.003 Bq/kg(l);
For energy 661.662 keV: 0.010 ± 0.004 Bq/kg(l);
For energy 1460.75 keV: 0.412 ± 0.341 Bq/kg(l).

Strontium-90 was determined by the carbonate sedimentation method with a carrier of nitrate extractions of the ashes from the vegetation, soil and milk. Before the carbonates settle, the strontium is cleaned out of the admixtures. The strontium carbonates are dissolved in a minimum amount of nitric acid; an yttrium carrier is added, and the solution is left for 14 days to accumulate. After establishing the radiochemical equilibrium between strontium-90 and yttrium-90, a sample is prepared of yttrium-90 hydroxides to measure its activity using a beta-radiometer device. The strontium-90 activity is calculated from the yttrium-90 activity. Measurements are taken using radiometer devices which include the following:

- a beta particle detector with an SBT-10 counter protected by 50 mm of lead,
- a PS02-4 counting device,
- a set of necessary electronic-physical equipment,
- the measurements are taken every 1-1.5 hours,
- - the sensitivity of this method is 0.05 Bq/kg,
- the method's error is 27.27%.

2.5 DOSE RECONSTRUCTION METHODOLOGY

Radiation from three component forms acts on humans:

- cosmic radiation;

- radiation from natural radionuclides which are scattered in the earth's crust, soil, air, water and other objects of the environment; of these the main contribution to the human radiation dose comes from K-40, U-238 and Th-232 in conjunction with decay products of uranium and thorium;

- radiation from artificial radionuclides. These may be formed during nuclear weapons tests and precipitate to the earth's surface in the form of local, tropospheric or global radioactive fallout. They also enter the environment when radioactive wastes are removed from atomic energy enterprises, nuclear fuel cycle enterprises, and enterprises and institutions which work with radioactive materials. They may also be formed for use in medicine, science, technology or agriculture.

All three components act on humans in the following manner:

- as external radiation (from radioactive materials being present in the near-surface air or which fall out to the earth's surface);

- as internal radiation (from inhaling radioactive materials, contained in the near-surface layers of the air, and through the use in food of products and drinking water which are contaminated by radionuclides).

The methods to reconstruct the doses of external and internal radiation assume the presence of two component parts: mathematical calculation models and their information content. Only when these two components correspond to the actual process occurring in the environment and in the human body can the calculated dose values correspond to the actual radiation doses to which people could be subjected in the conditions of a specific radiation situation.

Currently, mathematical models to calculate the radiation dose are rather well developed [1, 3, 7, 9, 10, 12, and 27].

2.5.1 EXTERNAL RADIATION

Given external radiation, the distribution of absorbed doses in the organs and tissues is close to equal. Thus, with an error not exceeding 10%, the absorbed gamma radiation dose in air, expressed in rads, can be used as an estimate of the effective dose of external radiation of a human in rems. Equation 1 gives the time the cloud is radiating (duration of the track formation) in a given point in the locale, hrs:

$$^\wedge t = \frac{0.2\sqrt[3]{q} + 0.32X}{V} \qquad \textbf{Eq. 1}$$

where $t_0 = X/V$ is the time of arrival of the explosion cloud to the given point in the locale (beginning of the formation of the track), hrs;

X is the distance from the explosion epicenter, km;

V is the average wind speed, km/hr;

and q is the explosive yield, kt (kilotons TNT equivalent).

$$t_{stop} = t_0 +^\wedge t \qquad \textbf{Eq. 2}$$

Equation 2 is the accepted time that cloud radiation stops (formation of the track) and the time of onset of fallout irradiating the locale with radioactive fission products begins, hrs post explosion. To calculate the radiation level in R/hr of any point in the area (X,Y,) at a definite moment of time t (hours), we used the following equations [4]:

$$R_t = \frac{10^{8.64} q t^{-\frac{1}{2}}}{1.75} \cdot \left[\frac{X}{hV}\right]^{0.2} \cdot \exp\left\{-21.27\left(\frac{X^{0.1346}}{hV}\right) - \left|\left(\frac{Y^2}{2G^2}\right)\right|\right\} \qquad \textbf{Eq. 3}$$

where

$$G = 0.14X^{0.75} \qquad \textbf{Eq. 4}$$

$$D_{cloud} = 79.2 \frac{R_{24} \cdot \hat{} t}{\left(\frac{X}{V} + \hat{} t\right)^{1.2}} \qquad \textbf{Eq. 5}$$

Equation 5 is the dose from the cloud, R.

R_{24} is the dose rate of gamma radiation at a given point of the track 24 hours after the nuclear explosion, R/hr.

The gamma radiation dose for any time interval is defined as the integral value of the dose rate acting in this interval since the time of the explosion:

$$D = 5R_1 t_1^{1.2}\left(\frac{1}{t_1^{0.2}} - \frac{1}{t_2^{0.2}}\right) \qquad \textbf{Eq. 6}$$

$$D_{fall} = 5R_t \cdot t^{1.2} \cdot t_{stop}^{-0.2} \qquad \textbf{Eq. 7}$$

where

D_{fall} is the total dose from gamma radiation fragments for the entire time period from the moment when fallout begins until its complete decay, R;
R_t is the dose rate measured at any time t after the explosion, R/hr;
t_{stop} is the time that fallout ceases, hours.

In general, one can estimate the total doses of external gamma radiation which could have affected the population according to the following formula:

$$D = \frac{D_{cloud}}{K_{cloud}} + D_{fall}\left(\frac{t_{open}}{24} - \frac{24 - t_{open}}{24K_{fall}}\right) \qquad \textbf{Eq. 8}$$

where

D_{cloud} is the dose during the track formation period;
D_{fall} is the gamma radiation dose caused by fallout;
t_{open} is the time spent by residents outdoors per day, hours (to estimate the maximum values, we chose 16 hours/day);
K_{cloud} is the reduction factor for gamma radiation provided by the buildings during the track formation period (considered to be equal to 1);
K_{fall} is the reduction factor for gamma radiation from fallout precipitates provided by local buildings (for adobe homes, it is equal to 13).

2.5.2 INTERNAL RADIATION

A feature of internal radiation is the non-uniform distribution of absorbed doses in the human body which is caused by the selective accumulation of radionuclides in individual organs and tissues. Relative to this, an estimate of equivalent radiation doses in these organs and tissues and a calculation of the effective dose of internal radiation both require the use of a special set of mathematical models, which adequately describe the process of entry and accumulation of radioactive fission products and the formation of equivalent doses. As a result of the existing inaccuracies in determining the radioactive contamination fields, the undefined character of dietary rations, the non-uniformity of contamination in agricultural production and the impossibility of accounting for inter-household ties, the errors for internal radiation doses can reach 100-200%. The method to calculate the internal radiation dose is based on a study of accessible materials in the earth sciences field [2, 6, 8, 11, 13-26, 28-31]. All the correlations and coefficients employed in this calculation method are taken from the work of Soviet scientists V.G. Riadov, L.G. Ilyin, K.I. Gordeev, Iu.S. Stepanov, V.M. Loborev, et al; they were all obtained by experiment at the Semipalatinsk Test Site with the direct participation of employees of the Kazakhstan NRIRME (National Research Institute for Radiation Medicine and Ecology, formerly known as Dispensary No. 4). This method permits us to obtain some averaged radiation doses within one population point via inhalation and oral ingestion (with milk) of iodine radioisotopes entering the thyroid, doses of whole body internal radiation from cesium-137 and bone radiation doses of strontium-90.

The main pathways for radioactive fission products to enter the human body are:

1. Inhalation: when breathing in contaminated air;
2. Digestion: when consuming food products contaminated by radionuclides;
3. Contact: as a result of intake via radioactive matter settling on the skin or mucous membranes;
4. Through wounds being contaminated by radioactive materials.

In the given case, we are examining the processes of radioactive materials migration which determine the internal radiation from ingestion and inhalation, which are the principal pathways of entry given the living conditions of the population. Other pathways of entry are specific in nature (industrial or other special conditions).

Reconstruction of the radiation parameters necessary to determine the human internal radiation dose is linked to empirical correlations with the given direct measurements of gamma radiation rates in the locale [11, 13, 14], which both simplifies the problem of obtaining the necessary initial data and significantly increases the reliability of the final estimates.

The average concentration of radioactive aerosols in the surface layer of air is expressed by $\bar{C}_{aer}$ in microCi/l:

$$\bar{C}_{aer} = \left(1 - 0.8e^{-0.25h}\right)\frac{D_{cloud}}{E \cdot {}^{\wedge}t} \qquad \textbf{Eq. 9}$$

where

h is the altitude to which the cloud rises, km;
D_{cloud} is the gamma radiation dose, R;
E is the average gamma radiation energy, Mev;
and $^{\wedge}t$ is the time of dose formation, hours.

The altitude to which the cloud rises is determined according to the formula:

$$h = 3.7q^{0.2} \qquad \textbf{Eq. 10}$$

where

q is the yield, kt.

The concentration of the i-th isotope, in microCi/l, is

$$\bar{C}^{i} = \bar{C}\frac{y^{i}(t_1)}{y(t_1)} \qquad \textbf{Eq. 11}$$

Equation 12 is the overall surface density of radioactive materials and the surface density of the i-th isotope in the point being studied along the track at the moment it ceases to form (t, hr), Ci/m^2.

$$Y_{gr(t_1)}, Y^{i}_{gr(t_1)} \qquad \textbf{Eq. 12}$$

The total fallout density of fission products is determined by:

$$Y = 0.1\ R_{24} \qquad \textbf{Eq. 13}$$

where

Y is in Ci/m^2;
and R is in R/hr.

The surface density of contamination by the i-th nuclide at 24 hours, in Ci/m^2, is:

$$Y^{i}_{gr(24)} = a_i \cdot R_{(24)} \cdot X^{bi}_{sd} \qquad \textbf{Eq. 14}$$

X_{sd} is the scaled distance;

$$X_{sd} = \frac{1.3X}{hV}$$ **Eq. 15**

Table 4. Values of a_i and b_i coefficients for several radioisotopes.

Isotope	a_i	b_i
I-131	0.00188	0.54
I-133	0.023	0.54
I-135	0.014	0.54
Cs-137	2.1E-5	1.17
Sr-90	2.15E-5	1.16

Contamination of pasture vegetation by individual biologically dangerous radioisotopes is determined, in Bq/kg, according to the correlation

$$Q^i_{veg} = 0.6Y^i_{gr} \cdot \left[1 - 0.87\exp\left(-4X_{sd}\right)^3\right]$$ **Eq. 16**

Intake of radionuclides by inhalation in microCi is

$$Q_i = C_i \cdot V \cdot t \cdot f$$ **Eq. 17**

where

Ci is the concentration of the i-th isotope in air, microCi/l;
V is the rate of pulmonary ventilation, l/min;
t is the inhalation time, min;
f is the fraction of activity which is held in the body during one inhalation.

The probable inhalation doses of internal radiation of humans is estimated according to reference [23]. This is done on the basis of information concerning the values of concentration of radioactive materials in the near-surface layer of air [12] relative to particles no bigger than 50 microns, due to the fact that the larger particles in practice cannot enter the human body through the respiratory pathways. According to the existing data from numerous investigations of the radionuclide composition of fractions of particles with dimensions d<50 microns, we can assume that the relationship of the activity of biologically significant radionuclides remains practically constant within the entire territory of the nuclear explosion track. This significantly simplifies a quantitative restoration of the radioactive composition in the links of the biological metabolic chain which lead to internal radiation of humans. The absorbed dose, in Gy, for inhalation is determined according to

$$H = \left(2.34 \times 10^{-13}\right) E_{eff} \cdot C_o \cdot T_{eff} \left(1 - \frac{T_{acc}}{T_{eff}}\right)$$ **Eq. 18**

where

E_{eff} is the effective energy, Mev/decay;
T_{eff} is the effective period of 50% elimination, sec;
T_{acc} is the effective period of 50% accumulation, sec;
C_0 is the initial concentration of the radionuclide in the body, Bq/kg;

$$C_o = Q_o \cdot f_2 / m$$ **Eq. 19**

where

Q_0 is the initial intake, Bq;
f_2 is the fraction of the nuclide entering the organ from the overall quantity in the body;
m is the mass of the organ, kg.

The individual doses entering through food pathways are calculated according to the method in reference [23] which assumes that only local food products are used; this is characteristic of residents of rural areas. Such estimates are sufficiently close to reality. The total intake of radionuclides into the body via the food chain is defined as the sum of annual intakes for the dose accumulation period. Then the intake of radioactive products in the second and subsequent years after the explosion is calculated accounting for the physical decay of the radionuclide from the moment of the explosion to the beginning of the current year with regard to the coefficients which correspond to the contamination of agricultural production via the roots. There is also a radiation dose from radionuclides entering the body by drinking milk.

The maximum activity of milk for the i-th isotope A_{max} (in Ci/l) is calculated according to the following:

$$A^i_{max} = \frac{0.6K_i \cdot G \cdot b \cdot Y^i_{gr(24)}}{g} \cdot \left[1 - 0.87 \exp\left(-4X^3_{sd}\right)\right]$$ **Eq. 20**

where

Y^i_{gr} is the contamination density of the locale by the i-th isotope 24 hours after the explosion, in Ci/m2;
X_{sd} is the scaled distance to the explosion epicenter;
G is the amount of grass eaten by grazing cows (50), kg;
b is the coefficient of solubility of the radioisotope depending on the scaled distance [12;.
g is the daily milk yield (10), l;
Ki is the coefficient dependent upon the type of radioisotope and its index of elimination with milk [12].

Table 5. Value of coefficient b_i for various scaled distances.

X_{sd} (km)	Up to 0.5	0.5 – 1	1 - 2	2 – 3	> 3
b_i	0.2	0.4	0.5	0.7	0.85

Table 6. Value of coefficient K_i for several radioisotopes.

Isotope	I-131	I-133	I-135	Cs-137	Sr-90
K_i	0.0346	0.0354	0.270	0.079	0.083

The radiation dose when radioisotopes are taken in with milk is calculated according to:

$$D = \frac{\left(2x10^{-8}\right)F \cdot E_{eff} \cdot T_{eff}}{m} \cdot \left(t_1 - \frac{1 - \exp^{-\lambda t_1}}{\lambda_{tot}} \cdot \exp^{-\lambda t_2}\right)$$ **Eq. 21**

where D is the equivalent radiation dose, Gy;
E_{eff} is the effective energy, Mev/decay;
T_{eff} is the effective period of 50% elimination, days;
$F = C * V * f$ is the rate of nuclide intake into the body, Bq/day;
C is the concentration of nuclide in the milk, Bq/l;
V is the consumption of milk, l/day;
f is the fraction of the nuclide entering the thyroid relative to the total intake into the body;
m is the mass of the organ, kg.
λ_{ti} is the decay constant for the combined rate of removal at time i. $\lambda_{tot} = \lambda_{phy} + \lambda_{bio}$, where λ_{phy} = the radioactive decay constant, or inverse of the physical half-life of the isotope, and λ_{bio} = the inverse of the biological half-life of the material.

3.0 RADIATION SITUATION AFTER INDIVIDUAL TESTS

3.1 RADIATION-HYGIENE SITUATION ON THE CONTAMINATED TERRITORIES AS A RESULT OF NUCLEAR WEAPONS TESTING IN CHINA FROM 1963 TO 1998

The presented materials, and the subsequent calculations of the effective equivalent doses of radiation showed that the principal contribution to the total dose of external gamma radiation of the population came from the tests conducted in 1966, 1967 and 1973. The total external gamma radiation dose to the population from these explosions was, for the Makanchy District 371 mGy; for Urdzhar 334.6 mGy; and for Taskesken 284 mGy. In those tests after 1973, the total external gamma radiation dose to the population was not greater than 4-5 mGy. Thus, the main total dose of external radiation was formed from 1966 to 1973.

One must note that it is namely in these years that we recorded rather high doses of internal radiation of the thyroid gland (close to 2 Gy), of the whole body at close to 100 mGy and of bone tissue at close to 1 Gy.

The starting point for studying the radiation situation in the population points of the Makanchy, Urdzhar and Taskesken districts were the investigations conducted in 1963 along the routes traversing these districts' territories. To determine the dynamics of radioactive isotopes from fallout entering into the soil, we determined the contamination level of the surface soil layer in 1963. Soil samples were taken every kilometer to determine the total activity. In every 20th sample, radioactive strontium and cesium were found. To estimate the dose, we used a transfer coefficient from the supply of Cs-137 in the soil to the absorbed dose. For the forest-steppe and the steppe-zone, it is 9.189 microGy/yr per 1 kBq/m^2. The soil sampling depth (0-1 cm) was justified by the purpose of the work, since, in order to conduct further work, it was necessary to know the surface contamination of the soil as it was in 1963 after atmospheric and surface explosions were banned.

The multi-kilometer route from Tailan to Bakhty traversed the study areas from the northen border of the Urdzhar District to the southeastern border of the Makanchy District. Along the route, the content of Sr-90 in the 0-1 cm surface layer of soil was in the range of 11 to 37 Bq/kg, and for Cs-137 from 5 to 37 Bq/kg; the doses of external radiation due to deposited Cs-137 were from 7 to 22 microGy in 1963 (Table 7; see also Figure 1).

The radiation situation on the territories of the Makanchy, Urdzhar and Taskesken Districts in 1967 was caused by global fallout from the stratosphere, and by radioactive fallout due to explosions conducted in the PRC.

Table 7. Tailan to Bakhty Route.

Sampling location (population point, route)	Total activity (Bq/kg)	Radionuclide content of Sr-90 (Bq/kg)	Radionuclide content of Cs-137 (Bq/kg)	Annual absorbed dose of external radiation (microGy)
18	1,411	37.00	12.77	--
19	1,272	16.50	10.99	--
(20) Taskesken	1,087	17.39	14.65	7.20
(21) Predgornoe	810	21.31	15.21	6.50
(22) Urdzhar (steppe zone)	833	12.14	22.57	16.90
(23) Urdzhar	994	18.50	36.89	21.76
(24) Nouely	1,087	25.27	14.95	9.62
25	1,226	10.95	4.92	--
(26) Makanchy	1,180	18.50	16.54	10.71
27	1,087	29.82	16.39	--
(28) Bakhty	1,180	26.64	16.28	11.50

Of the five explosions conducted between May 1966 and December 1967 (see Table 1), according to the meteorological conditions (wind direction and speed), only two could have affected the given territories (December 28, 1966 and June 17, 1967).

In April of 1967, soil samples were taken in the large population points of the Urdzhar, Makanchy and Taskesken districts. Table 8 presents the calculated and the actual total beta activity and the content of individual radionuclides in the soil (0-1 cm layer).

Table 8. Radionuclide concentrations in the surface layer of soil at 24 hours after the explosion of December 28,1966: sampling performed April 1, 1967 (Bq/kg).*

Surface layer soil contamination	Makanchy Calc.	Makanchy Actual	Urdzhar Calc.	Urdzhar Actual	Taskesken Calc.	Taskesken Actual
Total	2.6E+5	4.2E+6	2.26E+5	4.01E+6	1.72E+5	3.34E+6
I-131	1.09E+4	--	9.75E+3	--	8.25E+3	--
I-133	1.15E+5	--	1.01E+5	--	8.05E+3	--
I-135	5.21E+4	--	4.18E+4	--	2.91E+4	--
Cs-137	240	222	224	233	199	232
Sr-90	238	242	222	245	197	242

* *Note: These values were calculated from the dose per meter square, using the value of soil density typical for the Semipalatinsk region. Also, the samples were not taken until April 1, 1967; values were extrapolated back to 24 hours after the explosion of December 28, 1966.*

We could assume that the soil contamination will be less, since the radioactive precipitates fell on snow; as it melted, they could have migrated to the deeper soil layers. However, the obtained laboratory data agree well with the calculated data, which could be explained by the low-snow winter, when the fallout precipitated on practically bare ground. No vegetation or milk samples were taken, since the explosion was conducted in the middle of winter, when the internal radiation could only be determined by the inhalation intake, and the peroral intake was minimal, as there was no direct radiation of vegetation. The effect on the population is determined by the external radiation dose from the cloud, which for Makanchy, Urdzhar, and Taskesken was 0.14, 0.12 and 0.10 mGy, respectively, and also by the internal radiation doses via inhalation intake of radioactive fission products as the cloud passed over (Table 9).

The doses were calculated for a "standard" adult with the following parameters: age- 20-30 years; body weight- 70 kg; skeletal weight (without marrow)- 7 kg; thyroid gland weight- 0.02 kg; volume of inhaled air- 30 l/min.

Table 9. Calculated organ absorbed doses from inhalation after the explosion of December 28, 1966 (mGy).

Irradiated Organ (Responsible Radionuclide)	Makanchy	Urdzhar	Taskesken
Thyroid (Iodine)	33.7	31.1	26.4
Whole body (Cs-137)	1.14	1.12	1.06
Bones (Sr-90)	12.5	12.2	11.15

On June 17, 1967, in the PRC, a thermonuclear device was detonated with an estimated yield of either 0.4 or ~2 MT, depending upon the source of the data. In our calculations, the yield was taken to be 2 MT. After eight days, environmental samples (soil and vegetation) and milk samples were taken at the same population points. Table 10 presents the calculated and the actual total beta activity and the content of individual radionuclides in the objects under study.

From the tabular data, it is clear that the contamination of the environmental objects (soil and vegetation) and of the milk was caused by the June 17, 1967 explosion. The obtained laboratory data agree well with the calculated values, and the divergence of 5-10% falls within measurement error. Contamination exceeded average USSR levels for Zr-95 by 30 times, and for Cs-137 and Sr-90 by about 20 times.

The quantitative transfers of radionuclides along the links of the biological chain which end up being taken into the human body to a large extent depend on their solubility coefficient values, that is, the portions of the radionuclides which transition to the liquid phase. It is known that the overall solubility of nuclear explosion fission products which precipitate along the track depends on their radionuclide type and it increases with a reduction in particle size. When selecting values for the solubility coefficient, we started not from the overall solubility coefficient for the precipitates, but only that portion which comprises a biologically significant fractionation ($d < 50$ microns). When calculating the radionuclide concentration in milk, using the solubility coefficients shown in Table 5, we obtained some increase in the Taskesken population point, which is located farther from the explosion location; this increase was confirmed by measurements of actual milk samples.

The external radiation doses to the population were caused by the cloud passing over, and by the precipitating radioactive fission products; they were 143, 129 and 109 mGy for Makanchy, Urdzhar and Taskesken, respectively.

When calculating the probable radiation doses absorbed by organs and tissues from consuming milk, we took a daily consumption of 0.5 liters. The doses were calculated according to the results of laboratory investigations; the iodine-135 concentration was determined relative to the iodine-131/iodine-135 ratio 24 hours after the explosion (Table 11).

Table 10. Radionuclide concentrations in soil, vegetation and milk 24 hours after the explosion of June 17, 1967: sampling performed June 25, 1967 (Bq/kg).

Contamination of:	**Makanchy**	**Makanchy**	**Urdzhar**	**Urdzhar**	**Taskes-ken**	**Taskes-ken**
Surface soil layer	**Calc.**	**Actual**	**Calc.**	**Actual**	**Calc.**	**Actual**
Total	1.11E+7	2.52E+7	6.68E+6	1.32E+7	5.16E+6	1.24E+7
I-131	2.94E+5	2.84E+5	2.58E+5	2.61E+5	2.21E+5	2.46E+5
I-133	3.58E+6	2.61E+6	2.38E+6	2.41E+6	1.90E+6	2.14E+;6
I-135	2.18E+6	--	7.35E+6	--	5.04E+5	--
Cs-137	4.79E+3	5.12E+3	4.48E+3	4.59E+3	4.04E+3	4.26E+3
Sr-90	4.76E+3	5.13E+3	4.46E+3	4.51E+3	4.01E+3	4.32E+3
Vegetation						
I-131	2.80E+6	3.42E+6	2.48E+6	3.15E+6	2.12E+6	2.65E+6
I-133	3.42E+7	2.21E+7	2.28E+6	1.49E+7	1.82E+7	2.12E+7
I-135	2.08E+7	--	7.08E+6	--	4.84E+6	--
Cs-137	4.60E+4	3.84E+4	4.31E+4	3.68E+4	3.88E+4	3.17E+4
Sr-90	4.60E+4	3.86E+4	4.31E+4	3.62E+4	3.85E+4	3.15E+4
Milk						
I-131	7.26E+4	2.23E+5	6.69E+4	2.11E+5	7.98E+4	2.42E+5
I-133	1.81E+6	2.67E+6	1.65E+6	2.36E+6	1.99E+6	2.62E+6
I-135	8.57E+6	--	7.74E+6	--	9.36E+6	--
Cs-137	9.08E+3	7.76E+3	8.51E+3	7.11E+3	1.07E+4	8.83E+3
Sr-90	9.49E+2	7.97E+2	8.89E+2	7.50E+2	1.12E+3	9.31E+2

Table 11. Calculated organ absorbed doses from various routes of intake after the explosion of June 17, 1967 (mGy).

Irradiated organ	**Makanchy**	**Makanchy**	**Urdzhar**	**Urdzhar**	**Taskesken**	**Taskesken**
(Responsible radionuclide)	Inhaled	Peroral	Inhaled	Peroral	Inhaled	Peroral
Thyroid (Iodine)	1018	283	944	257	811	319
Whole body (Cs-137)	27.9	19.4	27.6	18.2	26.3	22.9
Bones (Sr-90)	306	275	303	257	289	324

The absorbed radiation doses in Taskesken village for milk consumption were somewhat higher, which was caused by a greater contamination of the given product.

The radiation situation on the territories of the study districts in 1972 was caused both by radiation precipitates from explosions in the PRC, and by global fallout from the stratosphere, as shown in Table 1.

The low-yield explosion of November 18, 1971 could not affect the southern territories of the Semipalatinsk Province. According to meteorological conditions (wind direction and speed), only the explosions of January 7, 1972 and March 18, 1972 could affect the radiation situation in these districts. The effect on the population from the January 7, 1972 explosion can be determined by the dose of external radiation from the cloud (it was 0.020, 0.018 and 0.014 mGy, respectively, for Makanchy, Urdzhar, and Taskesken) and by the external radiation doses from inhaling radioactive fission products as the cloud passed over, as detailed in Table 12.

Table 12. Calculated organ absorbed doses from inhalation after the explosion of January 7, 1972 (mGy).

Irradiated organ (responsible radionuclide)	Makanchy	Urdzhar	Taskesken
Thyroid (Iodine)	4.81	3.76	3.21
Whole body (Cs-137)	0.152	0.126	0.118
Bones (Sr-90)	1.67	1.38	1.29

On March 18, 1972, a thermonuclear explosion, with a 20-200 kt yield, was conducted in the PRC. In our calculations, we took the explosion yield to be 20 kt. In April of 1972, in the observed population points, we took environmental samples (soil and vegetation) and milk samples. Laboratory investigation results showed the presence of freshly produced fission products Sr-89, Zr-95, Ba-140 and radioiodines. The maximum concentration was found in the city of Ust'-Kamenogorsk in the Kazakh SSR; it was 37 Bq/m^2. In the village of Makanchy in April 1972, the concentration of Ba-140 was ~300 times higher. Comparative results of our calculated parameters and the averaged data obtained in the laboratory investigations are shown in Table 13.

Samples were selected 22 days after the explosion, which prevented us from determining the short-lived iodine isotopes with our employed methods. However, the results obtained for iodine-131 agree well with the calculations, and thus, with respect to the correlation of iodine-133 and -135 to iodine-131 24 hours after the explosion, the probable absorbed doses to the thyroid gland were determined according to the total iodine isotopes, as shown in Table 13.

Table 13. Radionuclide concentrations in soil, vegetation and milk at 24 hours after the explosion of March 18, 1972: sampling performed April 10, 1972 (Bq/kg).

Contamination of:	Makanchy	Makanchy	Urdzhar	Urdzhar	Taskes-ken	Taskes-ken
Surface soil layer	**Calc.**	**Actual**	**Calc.**	**Actual**	**Calc.**	**Actual**
Total	3.73E+4	4.44E+4	2.93E+4	4.35E+4	2.21E+4	3.51E+4
I-131	1.88E+3	2.05E+3	1.57E+3	1.65E+3	1.32E+3	1.44E+3
I-133	1.91E+4	--	1.54E+4	--	1.21E+4	--
I-135	7.56E+3	--	5.51E+3	--	3.76E+3	--
Cs-137	5.51E+1	4.91E+1	4.32E+1	5.05E+1	3.81E+1	4.08E+1
Sr-90	5.43E+1	4.73E+1	4.26E+1	4.50E+1	3.75E+1	4.09E+1
Vegetation						
I-131	1.81E+4	2.15E+4	1.51E+4	1.73E+4	1.27E+4	1.51E+4
I-133	1.51E+5	--	1.48E+5	--	1.16E+5	--
I-135	7.22E+4	--	5.29E+4	--	3.64E+4	--
Cs-137	5.29E+2	5.78E+2	4.15E+2	4.54E+2	3.66E+2	3.98E+2
Sr-90	5.22E+2	5.69E+2	4.11E+2	4.47E+2	3.61E+2	3.93E+2
Milk						
I-131	8.22E+2	2.57E+2	6.87E+2	2.09E+3	5.79E+2	1.72E+3
I-133	2.06E+4	--	1.72E+4	--	1.45E+4	--
I-135	1.03E+5	--	8.65E+4	--	7.28E+4	--
Cs-137	1.78E+2	1.94E+2	1.39E+2	1.47E+2	1.23E+2	1.34E+2
Sr-90	1.83E+1	2.00E+1	1.45E+1	1.59E+1	1.27E+1	1.39E+1

Table 14. Calculated organ absorbed doses from various routes of intake after the explosion of March 18, 1972 (mGy).

Irradiated organ	**Makanchy**	**Makanchy**	**Urdzhar**	**Urdzhar**	**Taskes-ken**	**Taskes-ken**
(Responsible Radionuclide)	Inhaled	Peroral	Inhaled	Peroral	Inhaled	Peroral
Thyroid (Iodine)	5.81	3.17	4.80	2.65	4.06	2.24
Whole body (Cs-137)	0.218	0.381	0.176	0.297	0.164	0.263
Bones (Sr-90)	2.38	5.31	1.92	4.21	1.78	3.68

The external radiation doses of the population were caused by the passing cloud and by the radioactive fission products precipitating; these were 0.581, 0.516, and 0.427 mGy, respectively, for Makanchy, Urdzhar, and Taskesken.

The radiation situation on the territories of the studied districts in 1973 was caused by the 2-3 MT yield thermonuclear explosion conducted in the PRC on June 27, 1973. In the calculations, we took the yield to be 2.5 MT. Samples were taken of objects in the environment (soil, vegetation) and of milk on July 10, 1973. Results of laboratory investigations indicated the presence of fresh fission products Sr-89, Ba-140 and radioiodines. The accumulation in the soil of Zr-95 + Nb-95 is the most sensitive index for the new appearance of nuclear explosion fission products from the atmosphere. Even though these isotopes began to decay rapidly after cessation of fallout, with half-lives of 65 and 35 days, respectively, their ground levels could still be defined sufficiently well. The average content of Zr-95 accumulated in the soil for the USSR after the Chinese explosion of June 27, 1973 was 148 Bq/m^2. In Taskesken village, the farthest away from the Lop Nur Test Site, its content in July of 1973 was 657,432 Bq/m^2. Comparative results of the calculated parameters and the average data obtained in the laboratory investigations are presented in Table 15.

The doses of external radiation of the population were caused both by the passing cloud, and by the fallout of radioactive fission products; they were 224, 202 and 172 mGy for Makanchy, Urdzhar and Taskesken, respectively.

Table 15. Radionuclide concentrations in soil, vegetation and milk at 24 hours after the explosion of June 27, 1973: sampling performed July 10, 1973 (Bq/kg).

Contamination of:	Makanchy	Makanchy	Urdzhar	Urdzhar	Taskes-ken	Taskes-ken
Surface soil layer	**Calc.**	**Actual**	**Calc.**	**Actual**	**Calc.**	**Actual**
Total	1.45E+7	2.06E+7	1.31E+7	1.95E+7	1.03E+7	1.65E+7
I-131	3.95E+5	4.40E+5	3.68E+5	4.05E+5	3.21E+5	3.43E+5
I-133	4.36E+6	4.63E+6	3.93E+6	4.42E+6	3.23E+6	3.16E+6
I-135	2.07E+6	--	2.34E+6	--	1.26E+6	--
Cs-137	5.78E+3	5.75E+3	5.34E+3	5.26E+3	4.89E+3	4.86E+3
Sr-90	5.75E+3	5.80E+3	5.32E+3	5.21E+3	4.87E+3	4.85E+3
Vegetation						
I-131	3.80E+6	4.51E+6	3.53E+6	4.01E+6	3.08E+6	3.49E+6
I-133	4.19E+7	9.91E+7	3.77E+7	9.01E+7	3.11E+7	9.14E+7
I-135	1.99E+7	--	1.65E+7	--	1.20E+7	--
Cs-137	5.54E+4	5.63E+4	5.13E+4	5.27E+4	4.71E+4	4.61E+4
Sr-90	5.52E+4	5.66E+4	5.11E+4	5.00E+4	4.68E+4	5.23E+4
Milk						
I-131	9.96E+4	2.67E+5	9.33E+4	2.56E+5	8.19E+4	2.26E+5
I-133	2.50E+6	3.96E+6	2.34E+6	3.73E+6	2.05E+6	2.69E+6
I-135	1.26E+7	--	1.17E+7	--	1.03E+7	--
Cs-137	1.12E+4	1.09E+4	1.01E+4	1.04E+4	9.31E+3	9.52E+3
Sr-90	1.14E+e	1.16E+3	1.06E+3	1.09E+3	9.72E+2	9.84E+2

Table 16. Calculated organ absorbed doses from various routes of intake after the explosion of June 27, 1973 (mGy).

Irradiated organ	**Makanchy**	**Makanchy**	**Urdzhar**	**Urdzhar**	**Taskes-ken**	**Taskes-ken**
(Responsible radionuclide)	Inhaled	Peroral	Inhaled	Peroral	Inhaled	Peroral
Thyroid (Iodine)	1377	386	1301	361	1140	317
Whole body (Cs-137)	23.1	23.5	22.4	21.6	21.6	19.9
Bones (Sr-90)	255	331	248	307	239	281

From 6/17/74 through 11/17/76 there were five known explosions in the PRC. According to the meteorological conditions (wind direction and speed), only the explosions of January 23, 1976 and September 26, 1976 could have affected the radiation situation in these districts. The underground explosion conducted on October 17, 1976 could not affect the southern portions of the Semipalatinsk Province territory, since the fission products from this explosion practically did not make it into the atmosphere. On November 17, 1976, a large yield thermonuclear explosion was conducted. The fission products from this explosion were ejected into the stratosphere in the northern hemisphere and were practically unseen in the near-surface atmosphere.

But on January 23, 1976, a low-yield underground nuclear explosion was conducted, with venting of radioactive fission products into the atmosphere. The radioactive fission products of this explosion were observed in various districts of the USSR. The effect on the population of the January 23, 1976 explosion can be determined from the dose of external radiation from the cloud, for Makanchy, Urdzhar, and Taskesken. These doses are 0.007, 0.006 and 0.005 mGy respectively, and by the doses of internal radiation from inhaling radioactive fission products as the cloud passed over.

On September 26, 1976, in the region of Lop Nur lake, a 20 kt low-altitude atmospheric nuclear explosion was conducted. Since no nuclear explosions were conducted in the atmosphere during the previous year, the atmosphere had been significantly cleansed of radioactive contaminants and the global background just prior to September of 1976 was low. Thus, the fission products of the Chinese explosion under examination led to a significant increase in the radioactive contamination of the atmosphere on the territory of the Soviet Union. Four days after the explosion, samples were taken from the environment (soil and vegetation) and of milk in the observed population points. The results of laboratory investigations indicated the presence of freshly produced fission products Sr-89, Zr-95, Ba-140 and radioiodines. The average annual value for the USSR of the level of accumulation in the soil of Zr-95+Nb-95 was 26.6 Bq/m^2. In Makanchy village, in September of 1976, the surface soil contamination was ~88 times higher. The comparative results of the calculated parameters and the averaged data obtained in the laboratory investigations are presented in Table 17.

Table 17. Radionuclide concentrations in soil, vegetation and milk 24 hours after the explosion of September 26, 1976: sampling performed September 30, 1976 (Bq/kg).

Contamination of:	**Makanchy**	**Makanchy**	**Urdzhar**	**Urdzhar**	**Taskes-ken**	**Taskes-ken**
Surface soil layer	**Calc.**	**Actual**	**Calc.**	**Actual**	**Calc.**	**Actual**
Total	3.43E+4	4.18E+4	2.90E+4	3.62E+4	2.17E+4	3.00E+4
I-131	1.67E+3	1.72E+3	1.49E+3	1.33E+3	1.26E+3	1.19E+3
I-133	1.80E+4	8.23E+3	1.56E+4	7.05E+3	1.22E+4	5.52E+3
I-135	8.13E+3	--	6.50E+3	--	4.45E+3	--
Cs-137	4.64E+1	4.61E+1	4.27E+1	3.86E+1	3.74E+1	3.45E+1
Sr-90	4.58E+1	4.56E+1	4.21E+1	3.93E+1	3.68E+1	3.51E+1
Vegetation						
I-131	1.61E+4	1.45E+4	1.43E+4	1.33E+4	1.21E+4	1.12E+4
I-133	1.73E+5	2.01E+5	1.50E+5	1.81E+5	1.18E+5	1.52E+5
I-135	1.30E+5	1.09E+5	6.24E+4	9.82E+4	4.28E+4	8.32E+4
Cs-137	4.46E+2	4.45E+2	4.10E+2	3.71E+2	3.60E+2	3.32E+2
Sr-90	4.39E+2	4.34E+2	4.04E+2	3.77E+2	3.53E+2	3.37E+2
Milk						
I-131	7.20E+2	2.18E+3	6.45E+2	2.02E+3	5.46E+2	1.72E+3
I-133	1.81E+4	2.74E+4	1.62E+4	2.55E+4	1.36E+4	2.12E+4
I-135	9.04E+4	--	8.12E+5	--	6.89E+5	--
Cs-137	1.50E+2	1.59E+2	1.38E+2	1.49E+2	1.21E+2	1.12E+2
Sr-90	1.55E+1	1.57E+1	1.43E+1	1.33E+1	1.25E+1	1.19E+1

The external radiation doses of the population were caused both by the passing cloud, and by the fallout of radioactive fission products; they were 0.525, 0.465 and 0.384 mGy for Makanchy, Urdzhar and Taskesken, respectively. A laboratory analysis of the milk samples did not permit us to determine the short-lived isotope iodine-135 given the methods we used. However, the results obtained for iodine-131 and -133 agree well with the calculated data, and thus, with respect to the correlation of iodine-135 to iodine-131 24 hours after the explosion, the probable absorbed doses to the thyroid gland were determined based on the total iodine isotopes (Table 18).

Table 18. Calculated organ absorbed doses from inhalation after the explosion of September 26, 1976 (mGy).

Irradiated organ (responsible radionuclide)	**Makanchy**	**Urdzhar**	**Taskesken**
Thyroid (Iodine)	1.97	1.77	1.50
Whole body (Cs-137)	0.063	0.061	0.056
Bones (Sr-90)	0.692	0.663	0.613

The radioactive fission products from the two Chinese nuclear explosions of January 23 and September 26, 1976 were recorded practically all over the territory of Kazakhstan. The maximum values of near-surface concentration and of atmospheric fallout for beta activity are shown in Table 19, where the December 1975 values were taken as "background".

Increased concentrations of total beta activity in the near-surface atmosphere in the city of Semipalatinsk were observed from September 27 to November 15, 1976 and they exceeded "background" values from 6 to 24 times. Increased concentrations of total beta activity in the atmospheric precipitates were observed in Semipalatinsk from September 27 to October 28, 1976, and they exceeded "background" values from 6 to 321 times. An isotopic analysis of aerosol samples after the explosion conducted on January 23, indicated the presence of a large quantity of short-lived isotopes. In the sample taken on January 29-30, 1976 in Semipalatinsk, the following was discovered: 2.0E-4 Bq/l Np-239 (on the day of sampling), 5.62E-5 Bq/l Ba-140, 3.55E-5 Bq/l Te-132, as well as Nd-147, Ce-141, 144, Mo-99, I-131, Be-7, Ru7-103, 106, Zr-95 and long-lived isotopes. After the explosion conducted on September 26, a large number of short-lived isotopes were also observed in the atmosphere. In Alma-Ata on October 16-17, the following were discovered: 1.07E-6 Bq/l U-237, 2.7E-5 Bq/l Ba-140, 2.0E-5 Bq/l Ce-141, 1.7E-5 Bq/l Zr-95, as well as Ru-103, Y-91, Sr-89, Nd-147, Be-7 and other long-lived isotopes, particularly 9.3E-8 Bq/l of Mn-54. Our investigations of the isotopic composition of the near-surface air and of atmospheric fallout conducted from October 8 to November 24 in the city of Semipalatinsk after the September 26, 1976 explosion are presented in Table 20.

Table 19. Maximum contamination of near-surface air and atmospheric fallout.

Location name	**Sampling date**	**Concentration, Bq/l**	**Ratio of concentration to "background" value**
After explosion of January 23			
Semipalatinsk	January 29-30	0.102E-3	162
Tselinograd	January 30-31	7.215E-5	163
Balkhash	Jan. 31 – Feb. 1	8.695E-5	214
Semipalatinsk	Jan. 31 – Feb. 1	7.659E-5	122
Balkhash	February 1-2	3.737E-5	92
Karaganda	February 4-5	3.589E-5	97
After explosion of September 26			
Almaty	October 11-12	9.879E-5	123
Semipalatinsk	October 11-13	1.665E-6*	24

Location name	**Sampling date**	**Fallout, Bq/m^2 per day**	**Ratio of concentration to "background" value**
After explosion of January 23			
Bakhty	January 29-30	62.9	28
Balkhash	Jan. 31 – Feb. 1	37.0	25
Semipalatinsk	February 5-6	70.3	63
After explosion of September 26			
Semipalatinsk	October 11-12	296*	157
Semipalatinsk	October 15-18	605*	321

**Note: These were personally measured, where the "background" was taken to be the average values before contamination.*

Table 20. Maximum and minimum content of radionuclides in the near-surface air and in atmospheric precipitates (at the time of sampling).

Radionuclide	Concentration in the air, Bq/l (range of values)	Contaminated fallout, Bq/m^2 (range of values)
La-140	(7.92 – 21.8)E-8	14.06 – 151.7
Ba-140	(6.88 – 19.0)E-8	12.21 – 133.2
I-131	--	2.22 – 3.7
Zr-95	(3.63 – 18.9)E-8	13.69 – 133.2
Nb-95	(2.04 – 11.8)E-8	4.44 – 84.36
Ru-103	(1.67 – 4.66)E-7	--
Ce-141	(4.55 – 26.3)E-8	3.70 – 169.5
Sr-89	--	17.76 – 57.72
Sr-90	--	1.48 – 2.96

In samples of vegetation taken in Semipalatinsk from October 13-18, the following radionuclides were discovered: La-140 (220 Bq/kg), Ba-140 (191 Bq/kg), Zr-95 (494 Bq/kg), Ru-103 (171 Bq/kg), Sr-89 (87 Bq/kg) and Sr-90 (16.3 Bq/kg). In the samples of milk, we discovered I-131 (10.4 Bq/l), Ba-140 (4.7 Bq/l), Sr-89 (5.92 Bq/l), and Sr-90 (0.96 Bq/l) of Sr-90. The dose rate from precipitated radioactive fallout was 0.07 microR/hr, and the dose of external radiation of the Semipalatinsk population was ~0.49 microGy. The radiation dose of critical organs from detected radionuclides was: bone tissue -- 0.07 microGy; lung tissue -- 0.004 microGy; and thyroid -- 1.01 microGy.

On September 17, 1977 an atmospheric nuclear explosion was conducted in the PRC whose yield was close to the yield of the explosion conducted there a year earlier on September 26, 1976. The altitude of the explosion was low, which resulted in dust particles and ground from the earth surface being included in the radioactive cloud. Thirteen days after the explosion, environmental samples (soil and vegetation) and milk samples were taken in the population points. The laboratory investigation results indicated the presence of freshly produced fission products Sr-89, Zr-95, Ba-140 and radioiodines. The average value for Zr-95 over the territory of the Soviet Union was 277.9 Bq/m^2 (recalculated for September 30, 1977). In Makanchy village, in September of 1977, the surface soil contamination for Zr-95 was 1413 Bq/m^2, that is, it exceeded the average for the Soviet Union by ~ 5.1 times. The comparative results of the calculated parameters and the averaged data obtained in the laboratory investigations are presented in Table 21.

The external radiation doses of the population were caused both by the passing cloud, and by the fallout of radioactive fission products; they were 0.454, 0.401 and 0.330 mGy for Makanchy, Urdzhar and Taskesken, respectively. The probable doses absorbed through inhalation (as the cloud passed) and perorally (consumption of contaminated milk) are presented in Table 22.

Table 21. Radionuclide concentrations in soil, vegetation and milk 24 hours after the explosion of September 17, 1977: sampling performed September 30, 1977 (Bq/kg).

Contamination of:	Makanchy	Makanchy	Urdzhar	Urdzhar	Taskes-ken	Taskes-ken
Surface soil layer	**Calc.**	**Actual**	**Calc.**	**Actual**	**Calc.**	**Actual**
Total	2.52E+4	3.71E+4	2.13E+4	3.1-E+4	1.53E+4	2.62E+4
I-131	1.48E+3	1.36E+3	1.33E+3	1.12E+3	1.11E+3	1.01E+3
I-133	1.44E+4	--	1.24E+4	--	9.31E+3	--
I-135	5.08E+3	--	4.01E+3	--	2.33E+3	--
Cs-137	4.48E+1	4.51E+1	4.13E+1	3.79E+1	3.63E+1	3.35E+1
Sr-90	4.41E+1	4.28E+1	4.06E+1	3.58E+1	3.57E+1	3.49E+1
Vegetation						
I-131	1.42E+4	1.45E+4	1.27E+4	1.17E+4	1.06E+4	1.11E+4
I-133	1.38E+5	1.83E+5	1.19E+5	1.21E+5	8.94E+4	1.41E+5
I-135	4.88E+4	--	3.85E+4	--	2.24E+4	--
Cs-137	4.30E+2	4.20E+2	3.97E+2	3.64E+2	3.49E+2	3.22E+2
Sr-90	4.23E+2	4.11E+2	3.90E+2	3.44E+2	3.42E+2	3.34E+2
Milk						
I-131	6.45E+2	2.18E+3	5.82E+2	2.02E+3	4.92E+2	1.72E+3
I-133	1.61E+4	2.74E+4	1.46E+4	2.55E+4	1.22E+4	2.12E+4
I-135	8.13E+4	--	7.28E+4	--	6.18E+4	--
Cs-137	1.45E+2	1.48E+2	1.33E+2	1.25E+2	1.17E+2	1.12E+2
Sr-90	1.50E+1	1.54E+1	1.38E+1	1.33E+1	1.21E+1	1.19E+1

Table 22. Calculated organ doses from various channels of intake after the explosion of September 17, 1977 (mGy).

Irradiated organ	Makanchy	Makanchy	Urdzhar	Urdzhar	Taskes-ken	Taskes-ken
(Responsible radionuclide)	Inhaled	Peroral	Inhaled	Peroral	Inhaled	Peroral
Thyroid (Iodine)	4.36	2.49	3.96	2.25	3.25	1.89
Whole body (Cs-137)	0.141	0.310	0.137	0.284	0.077	0.250
Bones (Sr-90)	1.53	4.35	1.49	4.00	0.837	3.51

On March 15, 1978, in China in the area of Lop Nur lake, a 20 kt yield nuclear explosion was conducted. An expedition to collect samples was brought together five days after the explosion. The results of the laboratory investigations indicated the presence of freshly produced fission products Sr-89, Zr-95, Ba-140 and radioiodines. The average accumulation of Zr-95 in the soil for the territory of the Soviet Union was 59.2 Bq/m^2. In Taskesken village, in March of 1978, the surface soil contamination for Zr-95 was 1679 Bq/m^2; that is, it exceeded the average Soviet Union values by ~28 times. The comparative results of the calculated parameters and the averaged data obtained in the laboratory investigations are presented in Table 23.

Table 23. Radionuclide concentrations in soil, vegetation and milk 24 hours after the explosion of March 15, 1978: sampling performed March 20, 1978 (Bq/kg).

Contamination of:	Makanchy	Makanchy	Urdzhar	Urdzhar	Taskes-ken	Taskes-ken
Surface soil layer	**Calc.**	**Actual**	**Calc.**	**Actual**	**Calc.**	**Actual**
Total	3.50E+4	5.53E+4	2.92E+4	4.84E+4	2.19E+4	3.96E+4
I-131	1.68E+3	1.53E+3	1.49E+3	1.36E+3	1.26E+3	1.15E+3
I-133	1.81E+4	8.20E+3	1.56E+4	6.68E+3	1.24E+4	5.59E+3
I-135	8.25E+3	--	6.56E+3	--	4.48E+3	--
Cs-137	4.63E+1	4.45E+1	4.25E+1	4.00E+1	3.74E+1	3.49E+1
Sr-90	4.57E+1	4.41E+1	4.19E+1	3.96E+1	3.69E+1	3.29E+1
Vegetation						
I-131	1.61E+4	1.14E+4	1.43E+4	1.04E+4	1.21E+4	8.53E+3
I-133	1.75E+5	1.23E+5	1.51E+5	1.21E+5	1.18E+5	8.23E+4
I-135	7.92E+4	--	6.30E+4	--	4.31E+4	--
Cs-137	4.45E+2	4.27E+2	4.08E+2	3.84E+2	3.60E+2	3.36E+2
Sr-90	4.39E+2	4.23E+2	4.02E+2	3.79E+2	3.54E+2	3.16E+2
Milk						
I-131	6.78E+2	1.83E+3	6.45E+2	1.65E+3	5.46E+2	1.72E+3
I-133	1.80E+4	2.61E+4	1.62E+4	2.15E+4	1.36E+4	2.12E+4
I-135	9.16E+4	--	8.19E+4	--	6.89E+4	--
Cs-137	1.49E+2	1.43E+2	1.37E+2	1.28E+2	1.21E+2	8.53E+1
Sr-90	1.55E+1	1.49E+1	1.42E+1	1.32E+1	1.25E+1	8.83E+0

The external radiation doses of the population were caused by both the passing cloud and by the fallout of radioactive fission products; they were 0.525, 0.465 and 0.384 mGy for Makanchy, Urdzhar and Taskesken, respectively. The probable doses absorbed through inhalation (as the cloud passed), and perorally (consumption of contaminated milk) are presented in Table 24.

Table 24. Calculated organ absorbed doses from various routes of intake after the explosion of March 15, 1978 (mGy).

Irradiated organ	Makanchy	Makanchy	Urdzhar	Urdzhar	Taskesken	Taskesken
(Responsible Radionuclide)	Inhaled	Peroral	Inhaled	Peroral	Inhaled	Peroral
Thyroid (Iodine)	4.80	2.78	4.36	2.50	3.70	2.11
Whole body (Cs-137)	0.123	0.319	0.119	0.293	0.110	0.259
Bones (Sr-90)	1.34	4.49	1.30	4.11	1.21	3.62

On December 14, 1978, in the PRC, in the area of Lop Nur lake, a 20 kt nuclear explosion was conducted. The effect on the population from the explosion can be determined according to the dose of external radiation from the cloud which was 0.022, 0.019 and 0.016 mGy for Makanchy, Urdzhar and Taskesken, respectively, and by the internal radiation doses from inhaling radioactive fission products as the cloud passed. The probable absorbed doses from inhalation (as the cloud passed) are presented in Table 25.

Table 25. Calculated organ absorbed doses from inhalation from the explosion of December 14, 1978 (mGy).

Irradiated Organ (Responsible Radionuclide)	Makanchy	Urdzhar	Taskesken
Thyroid (Iodine)	5.22	4.69	4.03
Whole body (Cs-137)	0.111	0.106	0.063
Bones (Sr-90)	1.21	1.17	0.658

On November 12, 1981, a low-altitude, 20 kt yield nuclear explosion was conducted in the PRC. According to the meteorological conditions (wind direction and speed), the given explosion could not affect the radiation situation of the Makanchy, Urdzhar and Taskesken districts of the Semipalatinsk Province. Four days later, environmental samples and milk samples were taken. The comparative results of the calculated parameters and the average data from the laboratory investigations are presented in Table 26.

Table 26. Radionuclide concentrations in soil, vegetation and milk 24 hours after the explosion of November 12, 1981: sampling performed November 16, 1981 (Bq/kg).

Contamination of:	Makanchy	Makanchy	Urdzhar	Urdzhar	Taskes-ken	Taskes-ken
Surface soil layer	**Calc.**	**Actual**	**Calc.**	**Actual**	**Calc.**	**Actual**
Total	4.49E+4	4.74E+4	3.78E+4	4.11E+4	2.88E+4	3.45E+4
I-131	1.83E+3	1.99E+3	1.64E+3	1.83E+3	1.38E+3	1.31E+3
I-133	2.14E+4	2.06E+4	1.86E+4	1.87E+4	1.50E+4	1.46E+4
I-135	1.17E+4	1.55E+4	9.50E+3	1.27E+4	6.81E+3	9.08E+3
Cs-137	4.69E+1	4.62E+1	4.33E+1	4.22E+1	3.83E+1	3.50E+1
Sr-90	4.63E+1	4.51E+1	4.26E+1	4.11E+1	3.78E+1	3.34E+1
Vegetation						
I-131	1.77E+4	1.56E+4	1.58E+4	1.42E+4	1.33E+4	1.22E+4
I-133	2.16E+5	1.72E+5	1.79E+5	1.51E+5	1.44E+5	1.16E+5
I-135	1.32E+5	1.14E+5	9.12E+4	1.01E+5	6.54E+4	7.19E+4
Cs-137	4.51E+2	3.78E+2	4.14E+2	3.49E+2	3.68E+2	3.09E+2
Sr-90	4.44E+2	3.63E+2	4.11E+2	3.45E+2	3.63E+2	3.06E+2
Milk						
I-131	7.80E+2	--	7.02E+3	--	5.97E+3	--
I-133	1.95E+4	--	1.76E+4	--	1.49E+4	--
I-135	9.81E+4	--	8.77E+4	--	7.47E+4	--
Cs-137	1.51E+2	1.22E+1	1.39E+2	1.17E+1	1.24E+2	1.05E+1
Sr-90	1.57E+1	1.30E+1	1.45E+1	1.12E+1	1.28E+1	1.07E+1

The results of the laboratory investigations indicated the presence of freshly produced fission products Sr-89, Zr-95, Ba-140 and radioiodines in the soil and vegetation samples. No freshly produced products were discovered in the milk samples, and this is explained by the fact that at that time, the longhorn cattle were housed in stalls, and they were given feed which had been prepared earlier, and had been covered against atmospheric precipitates. The presence of freshly produced radioisotopes in the vegetation was due to the fact that the vegetation had been taken from the open locale. The average value of Zr-95 for the territory of the Soviet Union was ~100 Bq/m^2. In the village of Makanchy, in November of 1981, the surface soil contamination for Zr-95 was ~2700 Bq/m^2; that is, it exceeded the average Soviet Union values by ~27 times. The concentration of dose-forming radionuclides in air is calculated according to the method described in a previous section. The absorbed radiation doses in mGy when radionuclides are inhaled into the body are presented in Table 27.

Table 27. Calculated organ absorbed doses from inhalation after the explosion of November 12, 1981 (mGy).

Irradiated Organ (Responsible Radionuclide)	**Makanchy**	**Urdzhar**	**Taskesken**
Thyroid (Iodine)	5.11	3.97	3.78
Whole body (Cs-137)	0.095	0.087	0.074
Bones (Sr-90)	1.04	0.942	0.813

The external radiation doses from the cloud were 0.021, 0.019 and 0.015 mGy, respectively, for Makanchy, Urdzhar, and Taskesken.

4.0 RADIOACTIVE CONTAMINATION OF SOIL AND FOOD PRODUCTS

4.1 RADIOACTIVE CONTAMINATION OF THE SURFACE LAYER OF SOIL AND MIGRATION TO DEPTH OF ISOTOPES IN THE DISTRICTS UNDER STUDY

Figures 2 and 3 present the distribution of long-lived isotopes along the route.

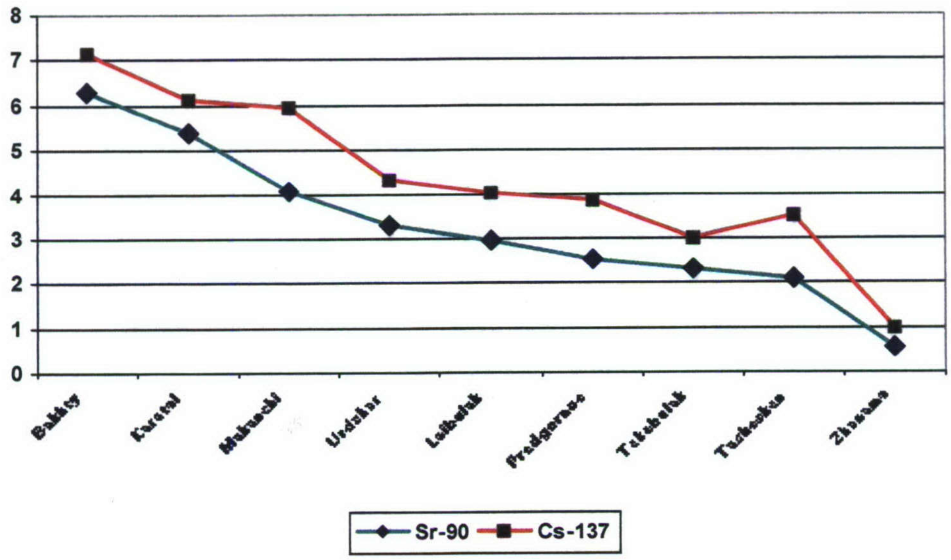

Figure 2. Distribution of long-lived isotopes in upper layer of soil along the Bakhty-Zhanama route.

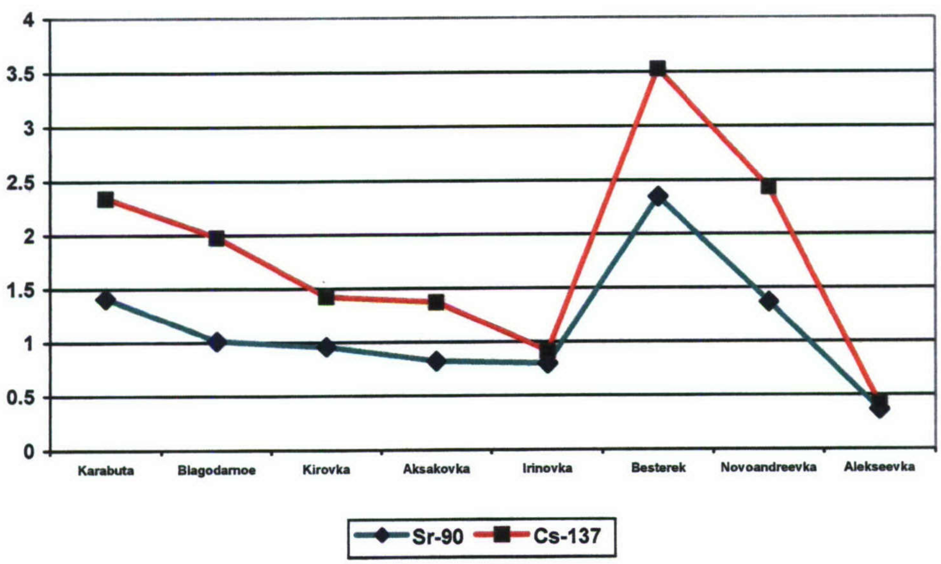

Figure 3. Distribution of long-lived isotopes in upper layer of soil along the Karabuta-Alexeevka route.

For the entire territory under study, the isotope composition is comprised of potassium-40, decay products of natural radioactive chains (uranium, thorium and actinium) and fission products (cesium-137 and strontium-90). According to the data in the table, we can easily trace an increased content of strontium-90 and cesium-137 along the first route (from Bakhty to Taskesken). For the second route, we note an increased content of the given isotopes in the population points of Besterek and Novoandreevka (Urdzhar District), as they are located not far from the probable axes of the passing radioactive tracks. The ratio of the specific activity of cesium-137 to strontium-90 is shown in Table 28.

Table 28. Ratio of long-lived products Cs-137/Sr-90 in the top soil layer.

Sampling point	Cs-137/Sr-90 ratio
Makanchy District	
Bakhty	1.132±0.379
Karatal	1.137±0.410
Makanchy	1.469±0.671
Karabuta	1.660±0.699
Blagodarnoe	1.956±0.889
Kirovka	1.491±0.640
Urdzhar District	
Urdzhar	1.324±0.553
Aksakovka	1.671±0.799
Irinovka	1.142±0.474
Besterek	1.503±0.629
Novoandreevka	1.780±0.734
Alekseevka	1.173±0.488
Taskesken District	
Laibulak	1.363±0.567
Predgornoe	1.529±0.646
Tekebulak	1.291±0.698
Taskesken	1.671±0.665
Zhanama	1.696±0.691

The global supply of Sr-90, according to the literature from 1985, is composed of 60% Cs-137, that is, the ratio of Cs-137 to Sr-90 for global fallout is 1.6 to 1.7. However, the results of our investigations in 1998 indicated that the correlation of Cs-137 to Sr-90 in the soil of the population points located along the first route (from Bakhty to Taskesken) is somewhat less than for global fallout (1.132 to 1.529). And only in Taskesken and Zhanama do they correspond. For the second route (from Karabuta to Alekseevka), the correlation data vary widely, from 1.291 to 1.956. The scatter in the correlations can be explained by the fact that the given territories were contaminated differently in different years, and also by the difference in the soils structures which result in different sorption capability for radionuclides, which in turn affects migration processes.

Table B-1 (Appendix B) presents the average results (from three samples) of analyzing the 0-5 cm layer of soil per the sampling plan. To determine the migration to depth of radioactive elements, we sampled soil at depths of up to 100 centimeters. During the selection of locations for sampling, we registered no significant difference in change of exposure dose rates, so the suggested sections were selected according to the criteria presented in section 2. During the sampling, instrumented investigations were conducted of the radioactivity distribution by layer. The average measurement values in the population points of Bakhty, Makanchy, Urdzhar and Taskesken depending on depth and type of recorded radiation are presented in Table B-2.

The results in the table indicate we were unsuccessful in obtaining a clear picture of the migration to depth of radioactivity using this method at these population locations. The distribution of all types of radiation was practically uniform for the entire depth of the small sampling pits. Some increases above average values for depth are observed for alpha radiation: in Bakhty, 1.6, 1.5 and 1.8 times increase for depths 20, 40 and 50 cm, respectively; in Makanchy, 1.3 times increase at 10 cm depth; in Urdzhar, 1.5 times increase at 40 cm; in Taskesken, 1.3 at 80 cm. The gamma radiation was uniform for all sampling pits; in Makanchy, there was a small 1.2 times increase at 40 cm depth. The beta radiation was uniform for all sampling pits with insignificant increases of ~1.1 times in Makanchy at 5 and 60 cm depth, in Urdzhar at 80 cm, and in Taskesken at 10 cm.

Tables B-3 through B-6 present the results of laboratory measurements of the pit soil samples in the population points of Bakhty, Makanchy, Urdzhar and Taskesken; Figures 4 through 7 present the distribution by layer of specific activity of the long-lived fission products Sr-90 and Cs-137.

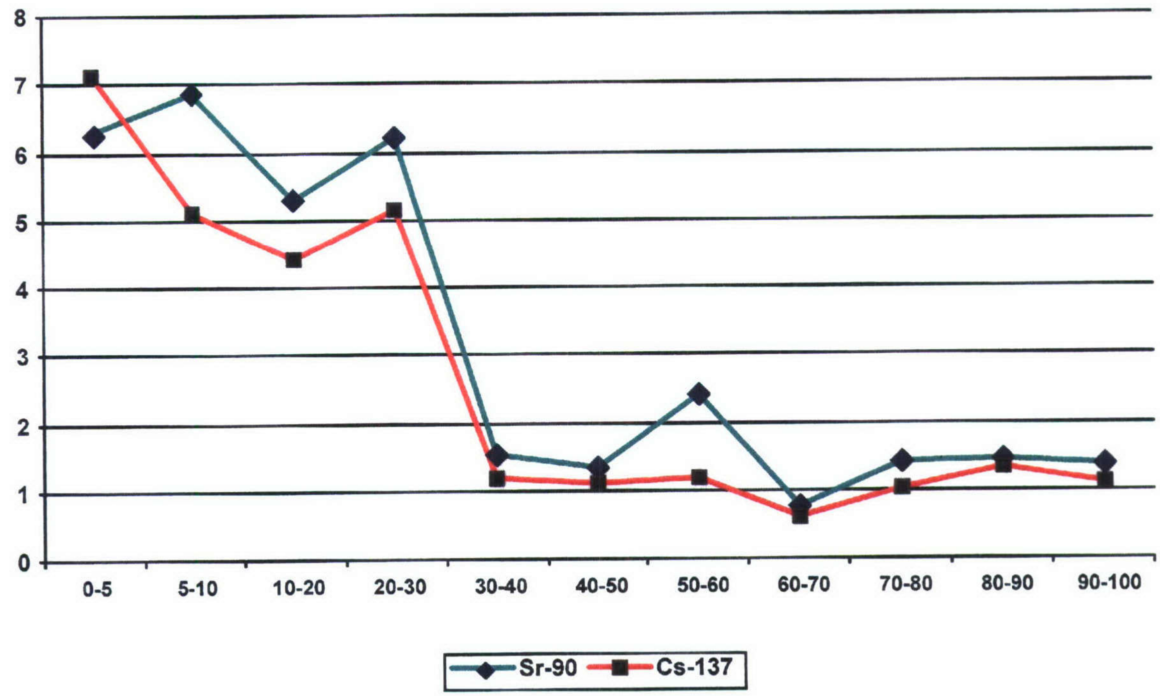

Figure 4. Migration of long-lived isotopes to depth at Bakhty (Bq/kg).

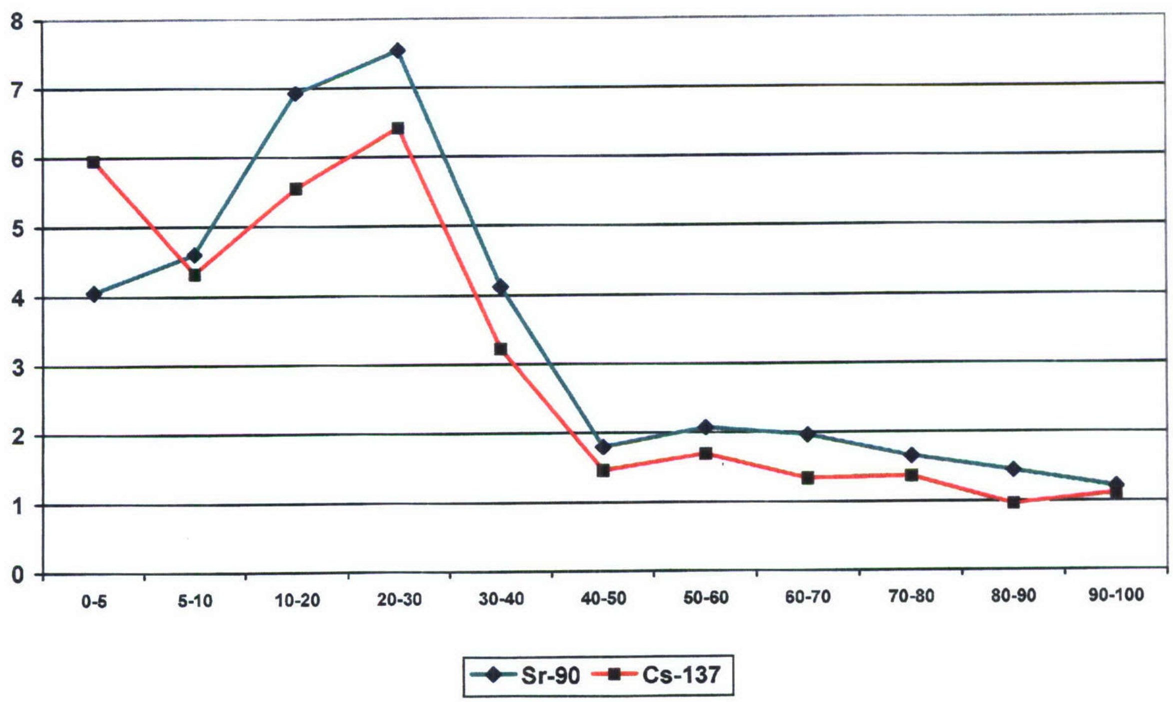

Figure 5. Migration of long-lived isotopes to depth at Makanchy (Bq/kg).

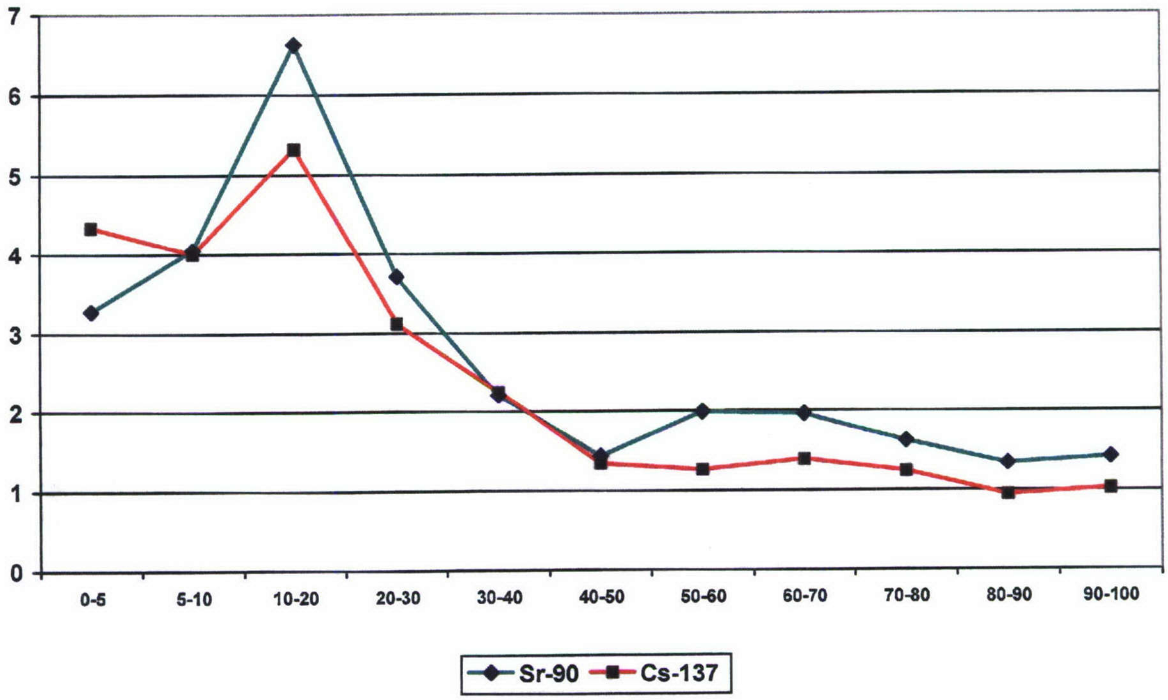

Figure 6. Migration of long-lived isotopes to depth at Urdzhar (Bq/kg).

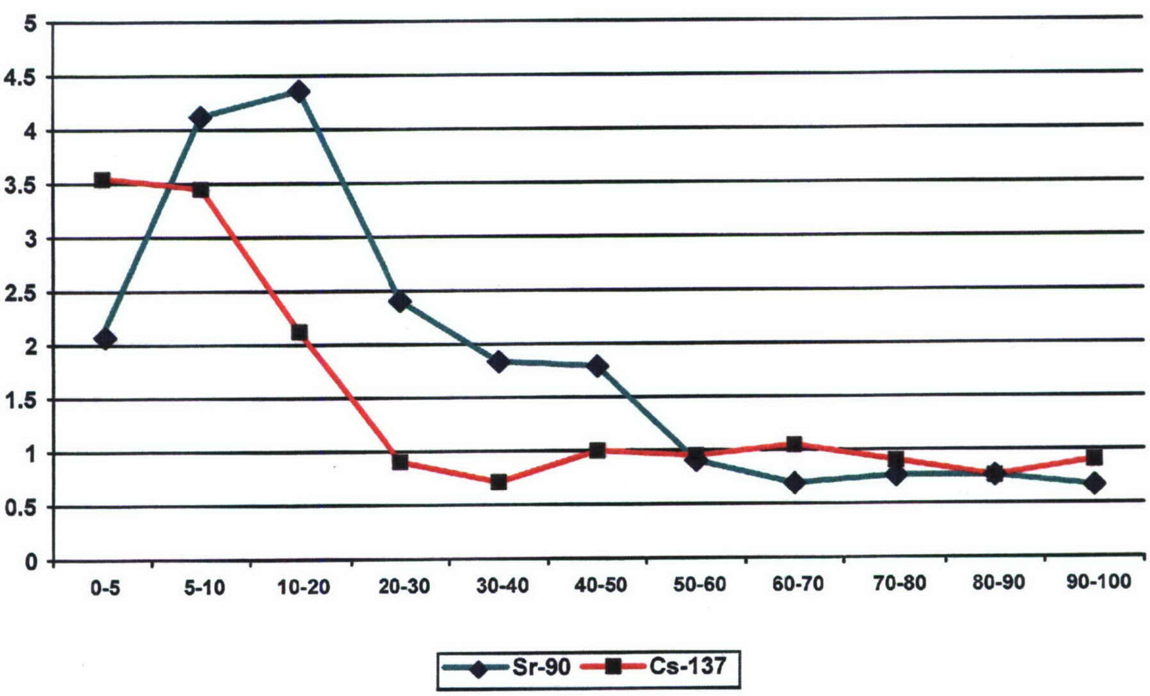

Figure 7. Migration of long-lived isotopes to depth at Taskesken (Bq/kg).

According to the tabular data, it is clear that 74.3% of the cesium-137 and 70.6% of the strontium-90 is concentrated in the 0-30 cm layer of soil; and beginning at 30 cm, we see a uniform distribution by depth (with some accumulation in the 50-60 cm layer). The migration of long-lived isotopes does not end at 100 cm. For all layers (excluding the 0-5 cm layer), the specific activity of St-90 is somewhat higher than that of Cs-137, and the total supply of Sr-90 to the studied depth exceeds the total supply of cesium-137 by 1.19 times.

The maximum content of Sr-90 (73%) and Cs-137 (76.3%) of the supply in the 0-100 cm layer of soil in Makanchy (Table B-4) is contained in the 0-40 cm layers. With a relatively uniform distribution of long-lived fission products in the lower layers, we noted an accumulation of Sr-90 in the 50-70 cm layer, and of Cs-137 in the 50-60 cm layer. The total supply of Sr-90 is ~1.12 times higher than that of Cs-137, and they do not stop migrating at 100 cm. And here, the specific activity of Sr-90 is somewhat higher than that of Cs-137, for all layers (excluding the 0-5 cm layer).

Table B-5 presents the results of measuring the layer by layer soil samples in Urdzhar village. 72.6% of the cesium-137 and 67.0% of the strontium-90 are concentrated in the 0-40 cm layers of soil, and beginning at 40 cm, we observe their uniform distribution with depth. We noted an accumulation of Sr-90 in the 50-70 cm layer. The total supply of Sr-90 exceeds that of Cs-137 by ~1.13 times, and the specific activity of strontium-90 is somewhat higher for practically every layer than that of cesium-137; and their penetration into the soil does not stop at 100 cm of depth.

The results of measuring the soil pit samples in Taskesken village (Table B-6) differ somewhat from the results in the other population points. According to the tabular data, it is clear that 81.5% of the strontium-90 is concentrated in the 0-50 cm layer of soil, and beginning at 50 cm, we observe its uniform distribution with depth. Roughly half of the Cs-137 (55.8%) lies in the 0-20 cm layer; at greater depth, the cesium distribution by layer is practically uniform. However, the migration of long-lived isotopes probably does not stop at 100 cm either. If the specific activity from 5 to 50 cm of Sr-90 is higher than in the lower-lying layers, we see some increase in the specific activity for Cs-137. The total supply of Sr-90 is ~1.25 times higher than that of Cs-137.

4.2 RADIOACTIVE CONTAMINATION OF VEGETATION

The intake of radioactive materials into the human body, with no nuclear testing, occurs partially from the soil-vegetation-animal-human chain. It has been established that the biological metabolic chain begins, in practice, not with the soil, but with grass in pastures. Thus, we monitored the vegetation growing on the territories of the studied districts. Vegetation contamination is caused by continuous global fallout, uptake into the feed system, and by secondary dusting from the surface soil. The accumulation levels of radioactive fragments in the vegetation depend, on one hand, on the fallout density, and on the other, on the growing conditions, and first of all, on the soil type, and on the performance of various types of agricultural work. The content of the specific activity in vegetation samples is shown in Table B-7.

The isotopic composition of the vegetation samples taken from the territory of the district under study is basically identical in qualitative composition to the soil samples. An increased content of strontium-90 and cesium-137 (similar to the content in soil) can be traced along the first route (from Bakhty to Taskesken). Along the second route, an increased content of the given isotopes is noted in the population points of Besterek and Novoandreevka (Urdzhar District), located closer to the probable axes of the radioactive tracks. The content of the specific activity in vegetation for strontium-90 varies from 0.243 (Zhanama) to 1.951 (Urdzhar) Bq/kg. The maximum content of cesium-137 was determined in the vegetation samples from Bakhty village with a value scatter for the first route of from 1.917 (Bakhty) to 0.601 (Tekebulak) Bq/kg. Along the second route, the scatter was from 0.501 (Alekseevka) to 0.969 (Besterek). In all vegetation samples, we identified the radionuclide ruthenium-106. For the radionuclides strontium and cesium, we calculated the coefficient of biological absorption (CBA = A_{veg} / A_{soil}) and the ratio of cesium to strontium in vegetation (Table B-8).

The obtained correlations for vegetation-soil for Cs-137 vary widely from 0.194 (Tekebulak) to 0.575 (Irinovka), that is, the content of Cs-137 in vegetation comprises from 19.4 to 57.5% of its content in soil. If we consider that the global fallout of Cs-137 is uniform for the entire district under study, then such a scatter in values can only be explained by the differing soil structure. The secondary dusting cannot contribute significantly to the contamination, since the density of vegetation growth in these districts is significant. Only in the population points of Bakhty, Karatal, Makanchy, Tekebulak and Taskesken, located in the steppe zone with less vegetation growth density, can the secondary dusting play a major role. Sr-90 accumulates in the vegetation mainly through the roots (3-10% of the content in soil with global fallout). According to our data, the transfer is from 14.6% (Tekebulak) to 63.2% (Karabuta), which confirms the presence of local fallout, whose solubility coefficient at such distances away from the explosion location is very high (85%). In addition, the transfer is determined by the nature of the soil, and does not exclude the role of secondary dusting. The correlation values of cesium to strontium in vegetation vary widely and differ from similar correlations in global fallout.

4.3 RADIOACTIVE CONTAMINATION OF LOCALLY-PRODUCED FOOD PRODUCTS

In the population points of the Makanchy, Urdzhar and Taskesken Districts which entered into our investigation zone, we took samples of milk, which is a significant part of the populations' daily food intake. The concentration of radioactive fission products in the milk samples is shown in Table B-9.The concentration of radioactivity in the food products depends directly on the contamination of the vegetation ground cover by fission products. The qualitative isotopic composition of the milk is identical to the vegetation samples. The content of specific activity in milk for strontium-90 in the study district varies from 0.014 (Alekseevka) to 0.124 (Bakhty) Bq/l. The maximum contamination with strontium is noted in the village of Bakhty. The maximum content of cesium-137 is found as well in the milk samples from Bakhty; the scatter of values for the entire district is 0.015 to 0.147 Bq/l.

Samples of meat, which has a definite significance in the populations' food rations, were taken in the population points of the district under study. The specific content of radioactive fission products in the meat samples is presented in Table B-10.

The meat samples are identical to the milk samples by qualitative composition. The content of specific activity in meat for strontium-90 varies in the district under study from 0.019 (Alekseevka) to 0.101 (Makanchy) Bq/kg. The maximum content of cesium-137 was found in the meat samples in Bakthy; the value scatter for the entire district is from 0.015 to 0.165 Bq/kg. Table B-11 presents the transfer coefficients for strontium-90 and cesium-137 from vegetation to milk and from vegetation to meat.

The results of measuring the concentration of radioactivity in milk and meat showed that the transfer of fission products from vegetation to milk for strontium-90 was between 0.053 and 0.123, and for cesium-137 0.042 and 0.105. 4.8-11% of strontium-90 and 3.0-12.8% of cesium-137 transfer from vegetation to meat. The quantitative content of K-40 in milk and in meat does not exceed the natural content of the radionuclide in these products.

Along with the meat samples, samples of animal bone were taken; these bones are used by the local population to make bouillon. The concentration of radioactive fission products in the animal bone samples is presented in Table B-12.

The accumulation of radionuclides in various organs of the human body, to a significant degree, depends on the quantity taken in with food products of stable nuclides of the same element or of the element of a chemical analog. So the accumulation of Sr-90 in bone tissue is determined mainly by the content of Ca in the food ration. We did not determine the content of Ca along the entire soil-vegetation-food products-human chain. The data in tables B-9 through B-11 are used to calculate the external radiation dose.

5.0 SUMMARY OF DOSE EXPOSURE

5.1 EXTERNAL GAMMA RADIATION DOSES TO THE POPULATION

In our calculations per the given model (2), we obtained the following results of possible doses (in mGy) for the territories of the population points located along the assumed axes of the tracks formed from a series of explosions (Table 29).

Table 29. External doses received (mGy) at three selected locations.

Date of Explosion	Makanchy			Urdzhar			Taskesken		
	From cloud	At the location	To the population	From cloud	At the location	To the population	From cloud	At the location	To the population
12/28/66	0.141	6.20	4.07	0.124	5.33	3.63	0.100	4.61	3.03
6/17/67	4.89	220.0	143.0	4.31	196.0	129.0	3.54	166.0	109.0
1/7/72	0.020	0.874	0.575	0.018	0.776	0.510	0.014	0.643	0.422
3/18/72	0.019	0.885	0.581	0.017	0.786	0.516	0.014	0.651	0.427
6/27/73	8.17	341.0	224.0	7.24	308.0	202.0	5.99	262.0	172.0
1/23/76	0.007	0.317	0.208	0.006	0.280	0.184	0.005	0.230	0.151
9/26/76	0.018	0.799	0.525	0.016	0.708	0.465	0.013	0.585	0.384
9/17/77	0.015	0.692	0.454	0.013	0.612	0.401	0.010	0.504	0.330
3/15/78	0.018	0.799	0.525	0.016	0.708	0.465	0.013	0.585	0.384
12/14/78	0.020	0.924	0.608	0.019	0.821	0.540	0.016	0.681	0.448
11/12/81	0.021	0.903	0.594	0.019	0.802	0.527	0.015	0.665	0.437
Total	13.34	573.4	375.1	11.80	515.0	338.2	9.73	437.2	287.0

Note: the doses received from the explosions of 9/26/76 and 3/15/78 were identical at each city owing to similar yields and weather conditions; this is not a misprint.

Considering the time of the explosion (winter, spring, summer, fall) and the behavior of the population depending on season, the actual doses to the population who lived from 1966 to 1981 in the population points of Makanchy, Urdzhar and Taskesken could be 369.3, 333.0 and 282.7 mGy, respectively. (Note slight differences from data presented in Table 28; not sure why this discrepancy exists.) The principal doses could have been obtained from the explosions conducted on 17 June 1967 (143, 129, 109 mGy) and 27 June 1973 (224, 202, 172 mGy). One should note that the principal action on the population occurred due to the doses from the fallout of radioactive fission products. The doses from the passing cloud are, as a rule, not greater than 3.7%.

The total of external radiation from fallout of radioactive precipitates to the Earth's surface is made up of many radionuclides which emit gamma radiation; however, only some of these contribute greatly to this dose. The annual human absorbed dose of external gamma radiation is caused by the fission products from nuclear explosions which have accumulated in the ground; we estimated this according to the supply of Cs-137. To estimate the dose, we use the transfer coefficient for the Cs-137 supply in the soil to the absorbed dose. For the forest-steppe and the steppe zones, it is 34 mrad/year per 1 Ci/km^2, which corresponds to 9.189 microGy/year per 1 kBq/m^2. The results of our calculations are presented in Table 30.

Table 30. Amount of Cs-137 in soil of investigated population points and annual absorbed dose of gamma-radiation for 1998.

Population Point	Amount of Cs-137, kBq/m^2	Annual absorbed dose, microGy
Makanchy District		
Bakhty	0.570±0.086	5.238±0.791
Makanchy	0.476±0.144	4.373±1.323
Karatal	0.490±0.156	4.503±1.433
Karabuta	0.187±0.055	1.718±0.505
Blagodarnoe	0.158±0.047	1.452±0.432
Kirovка	0.114±0.035	1.048±0.322
Urdzhar District		
Urdzhar	0.347±0.099	3.189±0.910
Aksakovka	0.110±0.035	1.011±0.322
Irinovка	0.073±0.021	0.671±0.193
Beseterek	0.282±0.080	2.591±0.735
Novoandreevka	0.194±0.058	1.783±0.533
Alekseevka	0.034±0.011	0.312±0.101
Taskesken District		
Laibulak	0.320±0.093	2.941±0.855
Predgornoe	0.309±0.098	2.839±0.901
Tekebulaк	0.240±0.112	2.206±1.029
Taskesken	0.281±0.081	2.582±0.744
Zhanaмa	0.078±0.024	0.718±0.221

For comparison, we can state that the annual absorbed dose from gamma radiation of naturally radioactive elements (K-40, U-238, Th-232) found in the soil (typical range is 123-788 microGy/year) is significantly greater.

5.2 INTERNAL RADIATION DOSES TO THE POPULATION

The total doses of internal radiation by inhalation or perorally (in mSv) are presented in Table 31. The doses from inhalation were determined according to the calculated concentrations of radionuclides in the air; and perorally, according to the measured radionuclide concentrations in milk.

The dose from explosions which are noted with an asterisk in Table 31 were calculated only for inhalation, since there was no direct contamination of animal feed, and consequently, the milk could not have been contaminated. The main contribution to the dose to the thyroid was due to iodine radioisotopes inhaled into the human body as the radioactive cloud passed over (from 63 to 78%). Given this, ~73% forms from I-133 and 135 effects, which agrees well with the composition of fission products from instantaneous fission after 24 hours. This also confirms the assumption that, at significant distances away from the explosion location, we have a practically non-fractionated mixture of radioactive fission products in the range of biologically significant fallout fractions ($d \leq$ 50 microns). Peroral intake is the determinant factor in forming doses of long-lived Cs-137 and Sr-90 isotopes entering the body in explosions with a yield on the order of 20 kt. The dose from consuming contaminated milk is ~2 times higher than the dose from inhaled intake.

Table 31. Internal radiation doses (mSv) at three selected locations.

Date of Explosion	**Makanchy**			**Urdzhar**			**Taskesken**		
	To thyroid	To whole body	To bone	To thyroid	To whole body	To bone	To thyroid	To whole body	To bone
12/28/66*	33.7	1.14	12.5	31.1	1.12	12.2	26.4	1.06	11.2
6/17/67	1301.0	47.3	581.0	1201.0	45.8	560.0	1130.0	49.2	613.0
1/7/72*	4.81	0.152	1.67	3.76	0.126	1.38	3.21	0.118	1.29
3/18/72	8.98	0.599	7.69	7.45	0.473	6.13	6.30	0.427	5.46
6/27/73	1763.0	46.6	586.0	1662.0	44.0	555.0	1457.0	41.5	520.0
1/23/76*	1.97	0.063	0.69	1.77	0.061	0.66	1.50	0.056	0.613
9/26/76	7.53	0.455	5.97	6.85	0.426	5.58	5.34	0.366	4.79
9/17/77	6.85	0.451	5.88	6.21	0.421	5.49	5.14	0.327	4.35
3/15/78	7.58	0.442	5.83	6.86	0.412	5.41	5.81	0.369	4.83
12/14/78*	5.22	0.111	1.21	4.69	0.106	1.17	4.03	0.063	0.658
11/12/81*	5.11	0.095	1.04	3.97	0.087	0.94	3.78	0.074	0.81
Total	3146	97.4	1210	2936	93.0	1154	2649	93.5	1167

* *Only exposure from inhalation calculated.*

The internal radiation doses (equivalent absorbed dose) from the intake of Sr-90 and Cs-137 via food products was calculated according to the method described in a previous section and are recorded in Table 32.

Table 32. Equivalent absorbed dose from food products in population points in 1998 (mGy).

Population Point	Milk		Meat		Bones		Total dose
	Cs-137	Sr-90	Cs-137	Sr-90	Cs-137	Sr-90	
Makanchy District							
Bakhty	0.315	35.97	0.142	11.14	0.018	7.915	55.50
Karatal	0.197	28.43	0.129	8.700	0.014	7.322	44.79
Makanchi	0.280	32.20	0.107	11.72	0.011	9.778	54.10
Karabuta	0.113	21.47	0.052	7.076	0.006	6.342	35.05
Blagodarnoe	0.096	17.99	0.049	7.308	0.004	4.392	29.84
Kirovka	0.094	10.73	0.041	3.944	0.004	3.558	18.37
Urdzhar District							
Urdzhar	0.270	29.88	0.098	10.90	0.010	8.962	50.12
Aksakovka	0.071	8.413	0.042	3.480	0.003	3.740	15.75
Irinovka	0.062	9.573	0.036	3.944	0.002	3.465	17.08
Besterek	0.137	27.27	0.075	8.004	0.006	5.815	41.31
Novoandreevka	0.124	19.15	0.054	5.800	0.005	4.776	29.91
Alekseevka	0.032	4.061	0.013	2.204	0.002	2.194	8.506
Taskesken District							
Laibulak	0.244	24.95	0.084	9.048	0.008	8.829	43.16
Predgornoe	0.175	24.08	0.072	8.004	0.007	8.654	40.99
Tekebulak	0.135	11.89	0.066	3.828	0.005	6.222	22.15
Taskesken	0.161	23.79	0.071	8.700	0.006	7.556	40.28
Zhanama	0.071	8.413	0.035	2.552	0.002	2.322	13.40

The initial assumptions are as follows:
-concentration of Cs-137 and Sr-90 in food products (meat, milk) and in water remained constant over the course of the year;
- intake of contaminated products into the body occurred on a daily basis over the year;
- doses were calculated for adults over a period of 50 years;
- the content of calcium in the studied products was not determined, therefore the protective effect from ingesting calcium was not considered;
- "standard human consumption": meat- 0.2 kg/day; milk- 0.5 l/day; water- 2.2 l/day; bones for bouillon- 0.2 kg/day;
- extraction of Sr-90 from the bones when boiled- 1%;
- Sr-90 and Cs-137 are uniformly distributed inside the organ or tissue under study;
- doses from Sr-90 are calculated for the bones and doses from C-137 for the whole body.

When calculating the doses, the following was assumed:
- the concentrations of Cs-137 and Sr-90 in foodstuffs (meat, milk) and water was assumed to be constant over each year;
- intake of contaminated products was considered to be daily and constant;
- according to the recommendations of the International Committee on Radiation Protection, we introduced a damage factor for Sr-90 of $N = 5.5$; $f = 0.09$ is the fraction of Sr-90 deposited in the bones, relative to the total intake from ingestion;

- doses were calculated for adults for a period of 50 years, from age 20 to 70;
- m_{bone} = 7 kg (standard man);
- f = 1 is the fraction of Cs-137 deposited in the whole body, relative to the total intake from ingestion;
- $m_{whole\ body}$ = 70 kg (standard man);
- t_1 = 365 days, the time of intake;
- t_2 = 50 years (18,250 days), the time at which intake stopped.

The obtained results show that the equivalent absorbed dose was caused by Sr-90. The contribution of Cs-137 to the total dose was ~0.9%.

6.0 OVERVIEW OF CANCER MORTALITY IN THE EXPOSED AND CONTROL DISTRICTS

Among the exposed population of the Makanchy District, we noted the significant dynamics of increase and decrease of the relative risk of cancer mortality in this period. The greatest relative risk was recorded in the years 1987-88 (1.76 and 1.76, respectively). In the four subsequent years, the relative risk of overall cancer mortality decreased, reaching 1.36 in 1996. Among the population in the exposed groups in the remaining districts, and also in the control district, the dynamics of overall cancer mortality increased slightly but not significantly so during all the years of the investigation.

An analysis of the dynamics of the level of fatal cancer cases for individual primary sites among the population of Makanchy District showed that only lung and breast cancer exceeded the indices for the control cases; the relative risks thereof were: for lung cancer, 1.63-3.53; and for breast cancer, 1.45-3.08. The average age of those who died of these cancers was roughly equal to that of the exposed and the control groups, i.e., 58.4 ± 1.1 years for lung cancer, and 61.2 ± 0.9 years for breast cancer.

Thus, it was only among the population of the Makanchy District that we recorded an excessive number of cases of these two cancers above the existing increase. The radiation dose of the population in this district was much higher than in the other two districts (Urdzhar, Taskesken).

If we consider that the principal effective equivalent doses to the exposed population were formed from 1967 to 1973, then we can assume that the latency period until observation of excess fatal cases of cancer was 12 to 15 years. An excess of fatal cancer cases occurred among people who were 40-50 years of age at the time of irradiation.

In the radiobiology literature, the issue of sensitivity of individual cancer sites to the effects of ionizing radiation is widely debated. According to the majority of investigators, hemoblasts are the most sensitive to the radiation factor [41, 42]. There is also no doubt regarding the high radiosensitivity of the thyroid gland [43, 44, 39, 45]. Investigations from the last years have shown that lung and breast cancers also are highly radiosensitive [46, 47].

The issue of the duration of the latency period between the effects of ionizing radiation and the emergence of malignant neoplasms is the subject of many scientists' investigations. In 1989 S.C. Darby (48), having analyzed the results of radiation therapy on 14,000 patients suffering from ankylosing spondylitis from 1935 to 1950, concluded that the risk of cancer occurrence in this group of individuals increased 20 years after irradiation and decreased after 30 years. Japanese authors [49], 45 years after the nuclear bombing of the Japanese cities of Hiroshima and Nagasaki, analyzed the onco-epidemiological data obtained as a result of observations of the irradiated contingent. The investigations were successful in establishing that the risk of developing leukoses in those irradiated began to increase 2-3 years after the bombing, reaching its peak after 5-7 years, and then began to decrease. However, even in 1981-85, in the population under study, a statistically significant increase in risk was noted. Excess mortality from other tumors began to emerge in the early 1960s (15 years after the nuclear bombing) for those who were of middle and advanced age at the time of the bombing. In those who were younger at the time of the bombing, the risk of emergence of malignant neoplasms appeared later, at the age where spontaneous solid tumors usually tend to appear. Depending on the patients' age and their dose, an increased risk was noted for cancer of the esophagus, stomach, breast, lungs, urinary tracts, ovaries, liver, and bile ducts.

One of the most complex issues before investigators is the question of the dose dependence of the frequency of inducing carcinogenesis [50, 51].

In the opinion of Russian investigators [52], there is a clear dependence of the frequency of development of malignant neoplasms in the circulatory and lymphatic tissues on the intensity and total dose of radiation. The authors suggest that the value of the dose, beginning from which an increase in mortality of the irradiated contingent of individuals from acute leukosis above the level of spontaneous indices becomes obvious, is more than 500 mGy per year and greater than 1 Gy in total. These data agree with the results of medical examinations [53]. However, several authors [54] suggest that the appearance of malignant neoplasms can be induced already when external radiation doses are on the order of 100 mGy. It has been calculated [55] that the risk of death from cancer at a dose of 10 mGy is 5 to 10 cases per 10 thousand of irradiated population. According to the data of other authors [56], a 10 mGy dose of ionizing radiation carries a lifetime risk of 10^{-4} for developing a case of cancer with a fatal outcome.

Independent investigators [57, 58] traced the fate of Japanese irradiated in Hiroshima and Nagasaki from 1975 to 1988. The authors confirm that the cancer risk was greatly reduced in earlier conducted investigations. The use of improved linear-quadratic risk models to extrapolate risks from high doses to low (from 10 to 100 mGy) doses permitted us to calculate that ionizing radiation has a fourfold stronger oncogenic effect than was considered earlier. Exposure to a dose of 1 mSv/year over a lifetime leads to 500 additional cancer deaths per 100,000 exposed individuals, if the entire dose were received at one time. In children, with other things being equal, the cancer risk turned out to be two times higher than in adults.

It has been established that the sensitivity to radiation carcinogenesis depends on the age of the irradiated individuals at the time of effect of the ionizing radiation [58]. Children are much more sensitive to the carcinogenic effects of radiation [59].

The majority of investigators note a dependence of the latency period duration in getting radiation-induced tumors on the age of the person at the time of irradiation [60, 61, 62]. It was shown that with acute leukoses, the latency period for individuals irradiated at an earlier age turned out to be shorter, whereas with myeloma, the latency period was longer for this age group. This condition was repeated in an analysis of the data for cancer of the lungs, stomach and breast. The frequency of radiation-induced cancer in these sites began to increase only when the individual subjected to radiation attained an age at which this form of cancer usually develops in non-irradiated individuals. As a result, the latency period in those who died from these cancers was longer the younger they were at the time of irradiation. Thus, with lung cancer in individuals irradiated at age 10-19, the latency period was 25-30 years, and in those irradiated at age 50, it was 10 years.

The results of our investigations confirm the opinion of the majority of the authors who noted the presence of dose limits (thresholds) in the appearance of radiation-induced tumors, as well as the modifying effect of the age at time of irradiation. Breast and lung cancer were recorded with more frequency among the exposed population groups in the Makanchy district, which received a greater radiation dose. The established duration of the latency period (13-15 years) allows us to ascertain the achievement of cancer effects in the group that was at age 40-45 at the time the effective radiation doses are formed. We can expect that in the subsequent years, excess oncological illness cases will appear (radiation induced solid tumors) among the population we monitored, whose age at time of irradiation was 20-30 years.

6.1 EPIDEMIOLOGICAL INVESTIGATION OF THE DYNAMICS AND STRUCTURE OF FATAL CANCER CASES AMONG THE EXPOSED AND CONTROL POPULATIONS

A descriptive epidemiological investigation of the dynamics of the extent of fatal cancer cases among the populations of the districts under study was conducted for the situation from 1949 to 1966. Tables C-1 and C-2 (Appendix C) present the dynamics of annual numbers in the radiation risk groups in the districts under study. The numbers given characterize only the population who continually lived in the observed districts. Not included in our data processing are individuals who arrive to these districts from other territories. The above-mentioned correction was done every 5 years: before 1970, according to retrospective analysis of materials; and after 1971, according to prospective actual data, obtained from local government authorities and census data in the monitored districts.

From the data in Table C-1, it is clear that the numerical composition of the monitored population in the Makanchy District increased from 20,000 (in 1949) to 39,500 (in 1996). Preliminary statistical processing of study materials for all the years did not uncover any significant differences in all the studied indices for cancer mortality of the populations in the Urdzhar and Taskesken Districts. Therefore, the study groups, as well as the indices of cancer mortality in these districts, were combined. We recorded a more than twofold increase in the population numbers for these districts for the 1949 to 1966 time period (37,500 to 87,000, Table 49). Such an increase in numbers is related not only to the demographic dynamics of birth, but also, in fact primarily, to the significant increase in the number of migrants arriving in these territories before 1963 (agricultural policy of the former USSR).

The numerical composition of the comparison groups (Kokpekty District of the Semipalatinsk Province), which practically did not suffer from radiation exposure during the testing period on the Semipalatinsk and Chinese test sites, possessed an adequately representative group of from 20,000 (1949) to 32,000 (1996) people. For the entire duration of the investigation period, we registered an insignificant prevalence of women over men. The age distribution in the study groups was adequate for all districts: age group 0-19, as a rule, constituted 40-45% of the overall numerical composition; age group 20 and above constituted 55-60%. The numbers in the age groups were roughly identical for all the years: 20-29 (up to 14%), 30-39 (up to 15%), 40-49 (up to 11%), 50-59 (up to 10%) and 60 and above constituted close to 5% of the monitored population.

The similar dynamics in the numbers allowed us to establish and correct standardized indices for cancer mortality of the monitored population.

The main objects of investigation were the death certificates of specific individuals who died from cancer. Before 1963, analysis of cancer mortality among the radiation risk groups was based on retrospective data obtained from death certificates and the statistics of the province administrations. However, beginning in 1964, employees of the Institute independently monitored cancer mortality in the population of the study districts on an annual basis; they then corrected the list of individuals who lived continuously in the study districts.

6.2 INVESTIGATION RESULTS

For the entire study period, among the population of the Makanchy District, we registered 1,813 fatal cancer cases (933 men, 800 women); in Urdzhar and Taskesken Districts, 2,576 (1,339 men, 1,237 women); and in the Control District of Kokpekty, 1,442 cases (702 men, 740 women).

The integrated indices of the level of overall cancer mortality for the total population quantity from 1949 to 1996 were: in Makanchy District, 122.4 cases per 100,000; in Urdzhar and Taskesken Districts, 88.5 cases per 100,000; and in the Kokpekty District (control), 102.4 cases per 100,000 population.

The dynamics of overall cancer mortality in the Urdzhar and Taskesken populations, as in the control Kokpekty District, did not undergo significant fluctuations over the years of the investigation. A preliminary processing of the investigation materials for the Kokpekty District permitted us to discover a peculiar excess: beginning in 1985 until 1996, the level of overall cancer mortality rose significantly and averaged 175.6 cases per 100,000 population. The integrated index for overall cancer mortality in this district for the previous 35 years (from 1949 to 1984) was 99.25 cases per 100,000 ($p<0.01$) as shown in Figure 8.

A further analysis of the investigation materials will be made of the above-mentioned references.

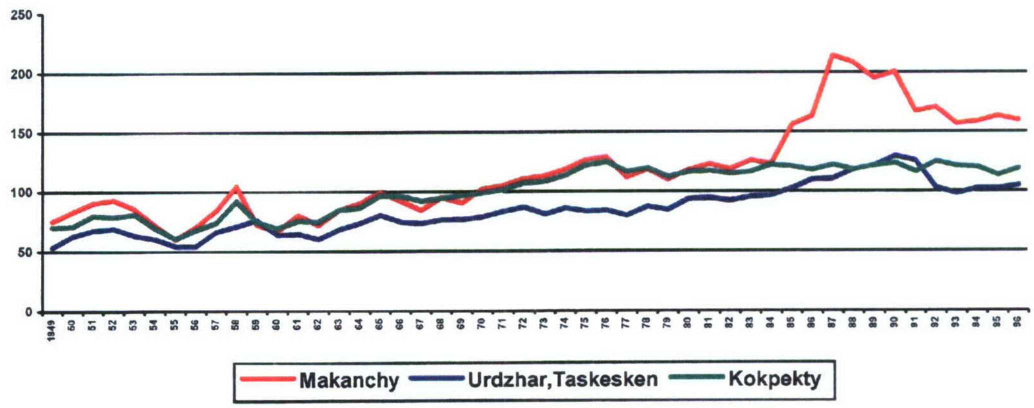

Figure 8. Dynamics of standardized total cancer mortality rates (SMR) of the population in the study districts (per 100,000 people).

6.3 DYNAMICS OF CANCER MORTALITY AMONG THE MONITORED POPULATION

The level of overall cancer mortality among the population was studied for three periods. The first period covers 1949 to 1963, prior to nuclear weapons testing in the PRC. The second period includes the period of nuclear weapons testing in the atmosphere (1964-1981). It is during this period that the principal effective equivalent radiation doses formed among the populations under study. The third period is the time after above ground testing was banned, and includes 1982 to 1996. One could expect to encounter post-radiation cancer effects within this period of time. As was noted above, the total effective dose of external gamma radiation for the residents of the Makanchy District was 375.1 mGy for the entire testing period. The Kokpekty District population (comparison group) received a total effective dose of not more than 50 mGy for all the years that nuclear weapons were tested at the Semipalatinsk test site.

An analysis of the standardized indices for overall cancer mortality (standard mortality ratio, or SMR) of the exposed population in the study districts and in the comparison groups indicated the lack of significant differences in these indices in all the districts studied in the first period (1949-1963). This index turned out to be the smallest among the population in the Urdzhar and Taskesken districts, 55.3-68.1 cases per 100,000 population. In the Makanchy and Kokpekty Districts, the standardized index of overall cancer mortality ranged from 70 to 84.2 cases per 100,000. In subsequent years, among the populations of the Urdzhar, Taskesken and the control Kokpekty Districts, the standardized index of overall cancer mortality, increasing slightly, reached the level of 104.5-118.7 cases per 100,000 population (Tables C-4 through C-6; Figure 8).

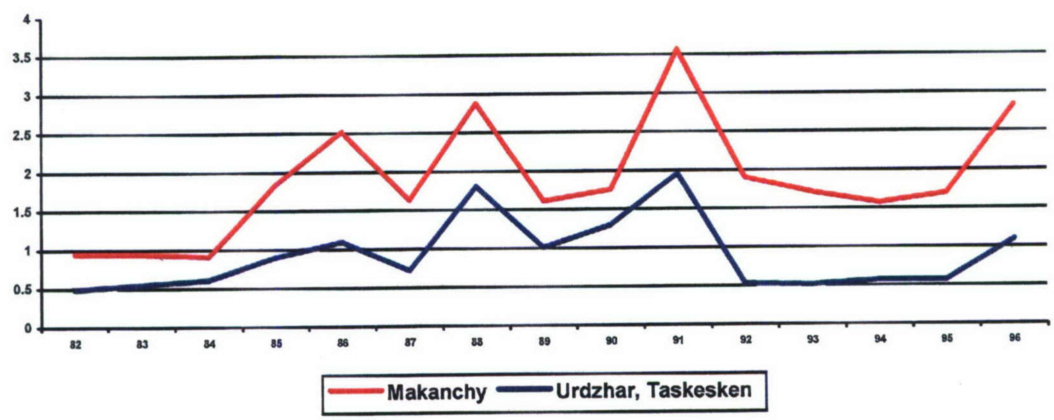

Figure 9. Dynamics of relative risk of lung cancer among the population of the Makanchy, Urdzhar and Taskesken Districts.

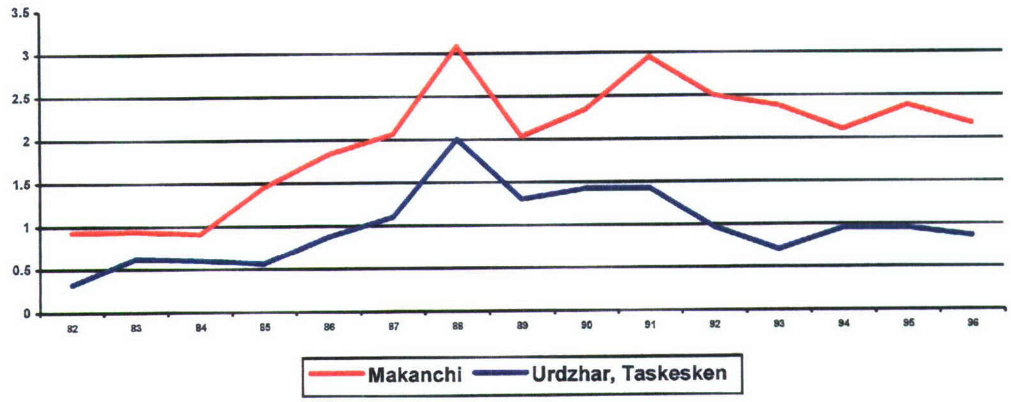

Figure 10. Dynamics of relative risk of breast cancer among the population of Makanchy, Urdzhar and Taskesken Districts.

A different picture was observed when analyzing the standardized index of the level of cancer mortality among the Makanchy District population. Before 1984, the index rose steadily from 75 to 122.9 cases per 100,000. Beginning in 1985 we noted a significant increase in this index from 155.6 in 1985 to 214.3 in 1987 ($p < 0.01$).

The excess fatal cancer cases among the Makanchy District population (1985-1987) comprised 78 cases (67.8%) as compared to the control index. During this period, the annual rate of increase in excess fatal cancer cases among the Makanchy District population was 22.6%. In the subsequent years (1988-1996), the excess spontaneous level of fatal cancer cases among the Makanchy District population amounted to 256 cases (75%). The annual rate of increase in excess fatal cancer cases among the Makanchy District exposed group was 8.3% The attributive risk of overall cancer mortality among the Makanchy District population for the period from 1985 to 1996 and the attributive percent risk were, by year:

Year	Overall Cancer Mortality	Attributive risk
1985	35.0	22.4%
1986	45.5	27.5%
1987	92.5	43.1%
1988	90.2	43.1%
1989	73.7	37.8%
1990	77.1	38.2%
1991	51.3	31.0%
1992	45.7	26.4%
1993	35.8	23.0%
1994	38.5	23.6%
1995	49.9	30.5%
1996	40.8	25.3%

The results of analyzing the relative risk of fatal cancer cases among the studied districts were obtained adequately per the above (Tables C-7 and C-8). Of the materials represented in the tables, it is clear that among the population of all the study districts, the relative risk of overall cancer mortality until 1984 did not exceed 0.77-1.17. Further the increase in relative risk up to 1.17 was recorded among the Makanchy District population from 1950 to 1952. In the subsequent years up to 1996, among the Urdzhar, Taskesken as well as the Kokpekty Control Districts, the relative risk of overall cancer mortality, as a rule, did not exceed 1.0.

Among the exposed population of the Makanchy District we discovered significant dynamics of increase and decrease in relative risk from 1985 to 1996. The greatest relative risk of overall cancer mortality was recorded in 1987 and 1988 (1.76, and 1.76, respectively). In the four subsequent years, the relative risk of cancer mortality among the population of this district slowly decreased, reaching the level of 1.36 (1992), and in the subsequent years to 1996 , it remained practically unchanged.

6.4 STRUCTURE OF CANCER MORTALITY AMONG THE POPULATIONS

The widespread materials on the study of the abundance of cancer among the Semipalatinsk Province population for 1949 to today indicate the high ethnic predisposition of the population to malignant tumors located in the gastrointestinal tract, particularly cancer of the esophagus. According to the data of the Republic's state statistical organs, cancer of the esophagus and stomach in the territory of Semipalatinsk Province for the 1960s, 1970s and 1980s was four times higher than the spontaneous level accepted as average indices for the former USSR.

Tables 33-36 present data on the structure of cancer mortality of the population in the study and control districts of the Semipalatinsk Province. As follows from the represented tables, from 1949 to 1972, among the populations of the study districts, fatal cases of cancer located in the gastrointestinal tract comprised the overwhelming majority (68-70.6%). In the next 10 years to 1982, we noted a tendency in the structure of cancer mortality toward a reduction in the overall number of cancers located in the gastrointestinal tract. During this period, they decreased significantly in both the exposed groups and in the control group ($p < 0.05$). A significant decrease in the number of fatal cancer cases located in the gastrointestinal tract was observed again in the following 10 years ($p < 0.05$), comprising 32.8-45.9% in 1992. One should note that in the Kokpekty Control District, from 1992 to 1996, the number of cancer cases located in the gastrointestinal tract again reached the initial levels (45.9-60.3%) (Table 33).

In the Urdzhar and Taskesken Districts (Table 35), and also in the Kokpekty Control District (Table 36), the reduction in the number of fatal cancer cases located in the gastrointestinal tract was accompanied by a moderately expressed increased in the number of cases of other located cancers (lung, breast). In these districts, no significant increase in the number of localizations was noted. A different picture in the dynamics of the structure of fatal cancer cases was observed among the exposed population in the Makanchy District. With the significant reduction in the number of gastrointestinal tract cancer cases from 1982 to 1996 (to 32% ($p < 0.01$), lung and breast cancer took first and second place. So, from 1972 to 1992, a threefold increase in the number of lung and breast cancer was noted (25% and 14.1%, respectively) (Table 33). These localizations also took first and second place in 1996 (22.2, 12.7%, respectively) in the structure of fatal cancer cases among the Makanchy District population.

Table 33. Structure of cancer mortality among the population of the study and control districts (percentage of total cancers).

	1963			1972			1982		
	Makanchy	Urdzhar, Taskes-ken	Kokpekty	Makanchy	Urdzhar, Taskes-ken	Kokpekty	Makanchy	Urdzhar, Taskes-ken	Kokpekty
GI tract	68.0	69.2	66.5	70.6	72	68.7	57.1	45.9	52.3
Lung	8.0	5.5	8.3	8.8	6.0	9.3	11.9	7.9	13.1
Breast	4.0	2.7	4.1	5.9	4.0	6.2	7.1	3.2	7.8
Other	20	22.6	21.1	14.7	18	15.8	23.9	43	26.8

	1992			1996		
	Makanchy	Urdzhar, Taskesken	Kokpekty	Makanchy	Urdzhar, Taskesken	Kokpekty
GI tract	32.8	33.2	45.9	34.9	34.4	60.3
Lung	25	8.7	17.9	22.2	10.9	10.5
Breast	14.1	6.9	7.6	12.7	6.4	7.8
Other	28.1	48.8	28.6	30.2	48.3	21.4

Table 34. Structure of cancer mortality among the population of Makanchy District (percentage of total cancers)

Cancer site	1949	1963	1972	1982	1992	1996
Esophagus	33.3	28	32.3	16.7	7.8	9.5
Stomach	26.7	20	26.5	19.0	10.9	9.5
Liver	6.7	8	5.9	4.8	4.7	3.2
Intestines	6.7	8	5.9	9.5	6.3	9.5
Pancreas	-	4	-	7.1	3.1	3.2
Lung	-	8	8.8	11.9	25	22.2
Urinary bladder	6.7	4	2.9	7.1	4.7	4.8
Kidney	6.7	4	2.9	7.1	4.7	4.8
Skin	-	-	-	-	1.6	1.6
Breast	-	4	5.9	7.1	14.1	12.7
Ovary	6.7	8	5.9	4.8	1.6	3.2
Corpus uteri	6.7	-	-	2.4	-	1.6
Cervix uteri	-	-	2.9	2.4	-	1.6
Gall bladder	-	-	-	-	1.6	3.2
Bronchi	-	-	-	-	4.7	3.2
Melanoma	-	-	-	-	3.1	3.2
ALL	-	-	-	-	3.1	1.6
CLL	-	4	-	-	-	-
AML	-	-	-	-	1.6	-
CML	-	-	-	-	1.6	1.6

Table 35. Structure of cancer mortality among the population of Urdzhar and Taskesken Districts (percentage of total cancers).

Cancer site	1949	1963	1972	1982	1992	1996
Esophagus	25.0	27.7	26.0	17.5	10.4	10.9
Stomach	30.0	22.2	24.0	15.8	11.3	11.8
Liver	10.0	8.3	8.0	4.7	3.5	3.6
Intestines	5.0	5.5	10.0	6.3	5.7	4.5
Pancreas	5.0	5.5	4.0	1.6	2.3	3.6
Lung	-	5.5	6.0	7.9	8.7	10.9
Urinary bladder	5.0	5.5	4.0	4.7	5.7	4.5
Kidney	5.0	5.5	4.0	6.3	5.7	4.5
Skin	-	2.7	2.0	4.7	2.3	1.8
Breast	-	2.7	4.0	3.2	6.9	6.4
Ovary	5.0	2.7	4.0	4.7	3.5	3.6
Corpus uteri	5.0	-	-	3.2	1.1	1.8
Cervix uteri	5.0	2.7	2.0	1.6	2.3	1.8
Gall bladder	-	-	-	3.2	1.1	0.9
Bronchi	-	-	-	3.2	3.5	3.6
Melanoma	-	-	-	6.3	3.5	3.6
ALL	-	-	-	3.2	2.3	1.8
CLL	-	-	2.0	-	-	-
AML	-	2.7	-	1.6	2.3	1.8
CML	-	-	-	-	1.1	0.9

Table 36. Structure of cancer mortality among the population of Kokpekty District (percentage of total cancers).

Cancer site	1949	1963	1972	1982	1992	1996
Esophagus	28.5	25	31.25	15.7	15.3	18.4
Stomach	28.5	20.8	25	15.7	15.3	18.4
Liver	7.4	8.3	6.25	2.6	-	7.8
Intestines	7.4	8.3	6.25	10.5	10.2	10.5
Pancreas	-	4.1	-	7.8	5.1	5.2
Lung	-	8.3	9.3	13.1	17.9	10.5
Urinary bladder	7.4	4.1	3.1	7.8	7.6	5.2
Kidney	7.4	4.1	3.1	7.8	7.6	7.8
Breast	-	4.1	6.2	7.8	7.6	7.8
Ovary	7.4	8.3	6.2	5.2	5.1	5.2
Corpus uteri	-	-	3.1	2.6	2.5	2.6
Colli uteri	7.4	-	-	2.6	2.5	-

6.5 DYNAMICS OF STANDARDIZED INDICES FOR CANCER MORTALITY FOR INDIVIDUAL POPULATION POINTS

The dynamics of the standardized indices for the levels of fatal cancer cases (standardized incidence ratio, or standardized mortality ratio [SMR]) at several primary sites among the population in the study districts underwent different and un-equivalent changes. In the control Kokpekty District and among the exposed groups in the Urdzhar and Taskesken Districts, we recorded a steady growth in the standardized indices of mortality level for individual primary sites of cancer. In all probability, this is tied to the increased quality of oncological treatment for the population and improved early diagnosis. (Table C-8)

Among the population of these districts, most prevalent were cancers of the esophagus, stomach, intestines, lung, and breast. We noted a significant growth in the SMR for lung and breast cancer. (Tables C-9 through C-11 in Appendix C, Figures 9 and 10 above).

Among the exposed population in the Makanchy District, the standardized mortality rates by primary sites displayed significant dynamics both toward increases, and reductions in the indices (Tables C-9 through C-11 and Figures C-1 through C-6 in Appendix C).

Before 1990, the standardized mortality rates from cancer of the esophagus and the stomach in this group were roughly at the same level, comprising an average of 20-24 cases per 100,000 population. In subsequent years, the mortality rates from these localizations decreased significantly, comprising 15.2 in 1996; that is, 15.2 cases per 100,000 ($p < 0.05$) (Table C-9). For all these years, cancers of the esophagus and stomach were 1.5 to 2 times higher among men.

Before 1982, the mortality rate for lung cancer among the population of this district grew slowly (from 6.9 cases per 100,000 in 1964 to 14.1 cases per 100,000 population in 1982). Beginning in 1985, we recorded a very significant increase in the standardized indices for mortality from lung cancer to 34.4-43.1 cases per 100,000 (1986-1991) (Figure 8).

For all these years, the mortality rates from lung cancer in this district were significantly higher than in the Kokpekty control district, and also among the exposed population of the Urdzhar and Taskesken Districts (Figure 9). One should note that for the entire investigation period, lung cancer among the men in the study districts was somewhat more prevalent as compared to the numbers of lung cancer cases in women (average 55.8-62.6% among men).

We consider that this distribution is related only to ethnic and hygenic factors, since no modifying effects of gender were established when defining the excess in such cancer localizations from 1985 to 1996. During this period of significant increase in lung cancer in the exposed population of the Makanchy District, we noted no changes in the gender distribution of cases of this cancer localization. As in previous years (1949-1984), lung cancers were more prevalent among males as compared to the same indices for women (61% vs. 39%, respectively).

The attributable risk (AR) and attributable risk percentage of lung cancer in the Makanchy District from 1985 to 1996 was:

Year	AR (cases/100,000)	AR (percentage)
1985	9.6	45.3
1986	18.1	60.3
1987	13.9	38.6
1988	23.2	65.1
1989	13.4	37.8
1990	14.0	42.8
1991	31.0	71.9
1992	20.3	47.3
1993	16.4	41.5
1994	13.1	36.3
1995	15.7	40.8
1996	22.9	64.6

The relative risk of fatal lung cancer cases among the Makanchy population before 1984 practically did not exceed 1.0, with the exception of 1962, when it was 2.02. Beginning in 1985, the relative lung cancer risk among the Makanchy population increased significantly (from 1.63 in 1987 to 3.53 in 1991) (Table C-12). Among the Urdzhar and Taskesken District populations, the relative lung cancer risk was practically less than 1.0, and only in 1988, 1990 and 1991 did it increase up to 1.29-1.95 (Figure 9, Table C-12).

From 1985 to 1996, there were 92 additional cases of lung cancer among the Makanchy District population as compared to the Kokpekty District. The annual rate of growth in lung cancer in this district averaged 19.6%.

For the same time period, there were 58 additional cases of breast cancer among the population of the Makanchy district population . The annual rate of growth in breast cancer in this district averaged 13.3%.

The same picture was observed in an analysis of the standardized indices of breast cancer mortalities. Before 1986, the fatal cases of this cancer were registered with roughly the same frequency among the population of the study districts. Beginning in 1987, fatal cases of breast cancer in the Makanchy district increased 2 to 2.5 times, comprising 19.2 cases per 100,000 population in 1987; in 1991, 27 cases per 100; and in 1996, 20.1 cases per 100,000 ($p < 0.01$).

A significant rise in relative breast cancer risk among the Makanchy District population was also noted in 1985 (1.45). In subsequent years until 1996, the relative breast cancer risk among women of the Makanchy district was significantly higher than that of the Urdzhar and Taskesken Districts (Figure 10, Table C-13).

The attributable risk (AR) and attributable risk percentage of breast cancer in the Makanchy District from 1985 to 1996 was:

Year	AR (cases/100,000)	AR (percentage)
1985	4.4	31.0
1986	7.4	45.3
1987	9.9	51.4
1988	13.0	67.5
1989	9.7	50.7
1990	12.5	57.2
1991	17.9	66.1
1992	14.4	60.0
1993	13.7	57.9
1994	10.8	52.3
1995	13.3	57.9
1996	10.8	53.9

In the control Kokpekty District during this period (from 1985 to 1996), the standardized mortality rate from breast cancer was three times lower and averaged 9.3 cases per 100 thousand population ($p < 0.01$).

The dynamics in the levels of the remaining locations of fatal cancer cases among the populations of the study districts underwent significant changes, as a rule, toward a small increase. No significant changes were noted in the standardized indices for other cancer primary sites. We registered an increase in the levels of cancer of the kidney and bladder among the Makanchy District population, but these differences were, as a rule, not significant.

Special attention was given to the dynamics of more radiosensitive cancers, such as hemoblasts [leukoses, or leukemias]. An analysis of the investigation results indicated that among the population of all the study districts, before 1985, leukoses were encountered extremely rarely, and in individual years (1954, 1957, 1961, 1964, 1966, 1972) only single cases were recorded. From 1985 to 1996, cases of leukoses in the study districts were recorded practically annually, but their quantity (1-2 cases per year) did not permit us to establish a connection between the growth in these cancer sites and exposure to ionizing radiation.

Of great significance when verifying the reasons for post-radiation cancer mortality is a determination of the modifying effect of age on the level and structure of both overall cancer mortality, and mortality from different cancer locations. Also, the age at the time of formation of the effective equivalent doses is of great importance in the realization of post-radiation effects. Table 64 presents the data on the distribution of the average age of the population in the study districts at time of death from oncological illness. From the tabular data, it is clear that the average population age for overall cancer mortality and the average age of death of the population from various cancer localizations in the study districts do not differ much. The table presents data on the locations with positive dynamic effects over the duration of the investigation. However, preliminary processing of the data to determine the average age of death from other cancer locations also did not permit us to discover any significant differences among the districts.

Table 37. Mean age of population in the study and control districts at time of death from cancer.

Cancer mortality by Primary site	Makanchy District		Urdzhar and Taskesken Districts		Кокpektinsky	Rajon
	1949-1984	1985-1996	1949-1984	1985-1996	1949-1984	1985-1996
	M±m	M±m	M±m	M±m	M±m	M±m
1. Total cancer mortality	62.2±1.3	59.5±0.9	61.3±1.2	62.3±1.3	62.2±1.3	61.4±1.1
2. Esophagus cancer	61.4±1.1	60.5±1.0	62.2±1.4	61.8±1.2	60.8±1.4	61.3±1.3
3. Stomach cancer	58.3±1.2	57.6±1.2	59.4±1.3	59.8±1.3	58.3±1.2	59.1±1.1
4. Lung cancer	59.7±1.3	58.4±1.1	60.1±1.1	59.5±1.3	59.7±1.3	58.4±1.2
5. Breast cancer	60.5±1.3	61.2±0.9	61.6±1.2	60.8±1.2	61.5±1.2	60.8±1.3

From the above, we can consider (with regard to the assumption that the main effective equivalent doses for the exposed population were formed from 1967 to 1973) that the latency period for overall mortality indices, and for such localizations as lung and breast cancer, was 13-15 years, and those who suffered the most were the individuals who were 40-45 years of age at the time of radiation. A similar age group distribution among whom excess lung and breast cancer occurred indicates that post-radiation effects begin to be realized at an age where spontaneous cancers are recorded.

7.0 DISCUSSION

Retrospective and prospective analyses were made of the formation of radiation situations in the population points of the southern districts in Semipalatinsk Province as a result of nuclear weapons testing. It was shown that, from 1967 to 1981, the territories of the Makanchy, Urdzhar and Taskesken Districts were contaminated 11 times by local radioactive fallout from atmospheric, surface and underground explosions conducted at the Lop Nur Chinese Test Site. This was confirmed by the appearance of freshly produced fission products, particularly iodine radioisotopes, strontium-89, barium-140 and others, in objects in the environment and in milk. The contamination of the surface soil layer in the study districts with freshly produced fission products exceeded the average values for the USSR by tens and even thousands of times. The ratio of long-lived fission products (Cs-137 to Sr-90) in the surface soil layer varied from 0.95 to 1.04, differing from that of local fallout (1.5). The concentration of radioactivity in locally produced food products depended directly on the contamination of vegetation from fission products. The results of measurements of the concentration of radioactivity in milk, in practically all the population points in the study districts, showed that, of the nuclear fission products, cesium and iodine were the two most abundantly found in milk (from 19% to 30% for cesium-137 and from 8% to 12% for iodine-131) which agrees well with the research of many authors (1, 32, 33).

The effective equivalent dose for the population who continually lived in the given territories was 466.7 mGy, 426.0 mGy and 376.2 mGy for the Makanchy, Urdzhar and Taskesken Districts, respectively.

We must note that the total external gamma radiation from the main dose-forming explosions (1966, 1967, 1973) was 371 mGy, 334.6 mGy and 384 mGy for the populations of the Makanchy, Urdzhar and Taskesken districts, respectively. It was specifically in these years that doses of internal radiation of the thyroid (close to 2 Gy) and of bone tissue (close to 1 Gy) were recorded. From 1949 to 1966, the dynamics of the numerical composition of the population in the study districts were monitored. As a control for the exposed group, we used the results of adequate investigations conducted among the population of the Kokpekty district in Semipalatinsk Province, who were practically unaffected at the time of the testing at the Semipalatinsk and Chinese test sites. The numerical composition and the age-gender characteristics of the control group were similar to those of the exposed groups.

A descriptive epidemiological investigation was made of the dynamics in the level and the extent of fatal cancer cases among the exposed populations and the control group from 1949 to 1996.

The carcinogenic effects of ionizing radiation has been a subject of attention by investigators and radiobiologists for many decades (34, 35, 36). Information concerning long-term radiation pathology in the form of carcinogenic effects can be acquired by performing epidemiological investigations when analyzing the effects of different sources of ionizing radiation, including nuclear weapons tests (37). As the author emphasizes, there exist definite difficulties in epidemiological investigations of the carcinogenic effects of ionizing radiation. They include the requirements for long-term observation of the exposed contingent due to the lengthy latency period between irradiation and the clinical emergence of tumors; the requirement for a complete and reliable registration of oncological illness and mortality; an exact estimate of the time of irradiation, its dose, distribution on the surface, and the characteristics of the radiation source for each individual; and the presence of control groups comparable in all respects to the study contingent, but not subjected to radiation.

According to E.E. Pochin, 1984 (38), it is especially difficult to select the statistical confidence criteria for the increased observed risk of tumors in the exposed vs. control group above the expected risk seen in the control group. This conclusion is most complex when studying frequently encountered forms of cancer, for which the deviation from the expected number of cases is more likely to be larger by statistical fluctuation; i.e., random. It has been established that the main modifying factors which significantly affect the changes in levels of structure of cancer mortality among the exposed groups is the value and the formation of the effective radiation dose, the age of the study contingent, the age at time of irradiation, and the nationality and gender (39, 40).

In our investigations, it was established that from 1985 to 1996, only among the Makanchy District population, where the dose of external gamma radiation was 375.1 mGy, did the level of overall cancer mortality rise significantly as compared to the previous period, comprising an average of 175.6 cases per 100 thousand population. In one particular year (1987), this index reached 214.3 cases per 100 thousand population.

BIBLIOGRAPHY

1. Ryadov V.G., *Aspects of Medical Evaluation of Radioactive Contamination of Objects in the Environment During Nuclear Explosions.* Author's abstract on dissertation in defense of Doctorate of Medical Sciences. 1966.

2. Gordeev K.I., Lebedev A.N., and Savkin M.N., *Method of Retrospective Restoration of the Radiation Situation Parameters which Determine External Radiation of the Population Along the Track from a Nuclear Explosion.* Bulletin of the "Semipalatinsk Test Site-Altai" scientific program, No. 1, 1994.

3. Loborev V.M., Sudakov V.V., Zelenov V.I., et al. *Reconstruction of Radiation Doses of the Altai Province Population from the Nuclear Explosion Conducted on 29 August 1949.* Bulletin of the "Semipalatinsk Test Site-Altai" scientific program, No. 1, 1994.

4. Mirgorodsky F.Ia., *"Simplified Formulas for Predicting the Radiation Situation During a Single Surface Nuclear Explosion."* Proceedings of the Central NII [Scientific Research Institute] of the Ministry of Defense. Collection 14, 1969.

5. Petrov R.V., Pravetsky V.N., Stepanov Yu.S., and Shal'nov M.I., *Protection Against Radioactive Precipitates.* Moscow, Medgiz, 1963.

6. Marei A.N., Borisov, B.K., and Barkhudarov, R.M. *Strontium-90 in Human Bone Tissue.* Hygiene and Sanitation, 1976, No. 8.

7. Gordeev K.I., Stepanov Iu.S., Vasin A.L., Yatsenko V.N., and Martishenia E.P., *External Gamma Radiation Doses in Districts Abutting the No-Access Zone Territories.* Report on scientific-research work. 1984.

8. Dibobeș I.K., et al. *Materials to Establish the Maximum Permissible Content of Strontium-90 in the Human Body, in Food Rations and in the Soil.* Cheliabinsk, 1963.

9. Stepanov Yu.S., *"Toward a Method for Estimating the Radiation Situation Along the Track of a Radioactive Cloud."* Bulletin of Radiation Medicine [BRM], No. 3, Moscow, 1965.

10. Dibobes I.K., et al. *"On the Issue of Predicting the Radiation Situation Along the Radioactive Cloud Track."* BRM No. 3, Moscow, 1965.

11. Ryadov V.G., Turapin S.L., Martynov A.P., and Volkov A.N., *"Migration of Locally Precipitating Radioactive Fission products of Nuclear Explosions along the Biological Chain."* BRM No. 3, Moscow, 1965.

12. Gordeev K.I., Kanunov A.I., Kryzhov B.A., and Stepanov Yu.S., *Doses of External Radiation and the Concentration of Radioactive Isotopes in Air During Underground Nuclear Explosions with the Ejection of Ground.* BRM No. 4, Moscow, 1969.

13. Gordeev K.I., Martinov A.P., Ryadov V.G., and Ter-Saakov A.A., *Radioactive Contamination of Grass in Pastures During Underground Nuclear Explosions with the Ejection of Ground.* BRM, No. 4, Moscow, 1969.

14. Gordeev K.I., Linkov P.M., Martinov A.P., and Ryadov V.G., *Transfer to Milk of Radioactive Fission products from Underground Nuclear Explosions with the Ejection of Ground When Cattle are Grazing in the Local Fallout Zone.* BRM, No. 4, Moscow, 1969.

15. Gordeev K.I., Kuznetsov E.S., and Ryadov V.G., *"On the Content of Biologically Significant Radio-Strontium in Local Tracks of Underground Nuclear Explosions."* BRM No. 4, Moscow, 1970.

16. Ivin I.S., Dobryakova G.V., and Panchenko I.Ya., *"Migration of Cs-137 and Sr-90 in the Food Ration - Milk Link When Cattle are Grazing."* BRM No. 4, Moscow, 1970.

17. Ryadov V.G., Gordeev K.I., and Loborev V.M., *"Materials for Estimating the Content of Radioactive Iodine in Local Radioactive Precipitates During Underground Nuclear Explosions."* BRM No. 4, 1969.

18. Fayer S.M., *Toward a Methodology for Calculating the Absorbed Dose in the Human Thyroid from Radiation of Radioactive Iodine Isotopes.* BRM, No. 4, 1969.

19. Dibobes I.K., Ospanov D.P., Radzievsky G.B., Shishkin V.F., Moiseev A.A., and Popov O.V., *Estimation of the Values of Inhalation Intake into the Human Body of Fission Products During the Formation of the Radioactive Track of a Radioactive Cloud.* BRM, No. 4, 1968.

20. Dibobes I.K., et al. *"On the Issue of Strontium-90 Transfer to the Human Food Ration via Ground and Atmospheric Paths of Contamination."* BRM No. 4, Moscow, 1965.

21. Guliakin I.V. and Yudintseva E.V., *Radioactive Fission Products in the Soil and in Vegetation.* Moscow, Gosatomizdat, 1962.

22. Israel Yu.A., *Isotopic Composition of Radioactive Precipitates.* Gidrometizdat, Leningrad, 1973.

23. Kozlov V.F., *Handbook on Radiation Safety.* Moscow, Energoatomizdat, 1987.

24. Zakutinsky D.I., Parfenov Yu.D., and Selivanova L.N., *Handbook on Toxicology of Radioactive Isotopes.* Moscow, 1962.

25. Grechushkina M.P., *Tables of the Composition of U-235, U-238 and Pu-239 Instantaneous Fission Products.* Moscow, Atomizdat, 1964.

26. Gusev N.G., Rubstov P.M., et al. *Radiation Characteristics of Fission Products.* Handbook, Moscow, Atomizdat, 1974.

27. Beck H.L. and Krey P.W., *Radiation Exposure in Utah from Nevada Nuclear Tests.* Science 1983, Vol. 220, No. 4592, pp. 18-24.

28. Middleton L.J., Rassel R.S., and Greer E.N., *The Retention of Fallout on Cereals Ripe for Harvest.* In: Progress Nuclear Energy, Vol. 3., No.. VI, 1961.

29. Rassel R.S. and Possingham J.V., *Physical Characteristics of Fallout and its Retention on Vegetation.* Progress Nuclear Energy, Vol. 3, No. VI, 1961.

30. Loutit J.F. and Rassel R.S., *General Conclusions.* In: Progress Nuclear Energy. Vol. 3, No. VI, 1961.

31. Sample results of National Air and Radiation Environmental Laboratory. July 8, 1994.

32. Lengemann F.W. and Swanson E.W., *A Study of the Secretion of Iodine in Milk in Dairy Cows Using Daily Oral Doses of I-131*, Journal of Dairy Science, Vol. 40, No. 3, 1957.

33. Squire H.M., Middleton L.J. Sansom B.F., and Coil C.R., *Experiments on the Metabolism of Certain Fission Products in Dairy Cows.* Radioisotopes in Scientific Research. Proceedings of the I (UNESCO) International Conference, 4, Pergamon Press, 1958.

34. Strel'nova V.N. and co-authors. *Blastomogenic Action of Ionizing Radiation.* Moscow, Medicine. 1964. 383 pp.

35. Vasilenko I.Ya., *Blastomogenic Action of Radioactive Products.* Issues of Oncology, 1982, Vol. 28, No. 1. pp. 76-83.

36. Beebe G.W., *Studies of Cancer Among the Japanese A-Bomb Survivors*. Cancer Invest. 1988, vol. 6, no. 4, pp. 417-426.

37. Moskalev Yu.N., *Long-Term Consequences of the Effects of Ionizing Radiation.* Moscow, Medicine. 1991. pp. 464.

38. Pochin E.E., *The Epidemiology of Radiation Carcinogenesis in Man.* International Conference IRPA Radiation-Risk-Protection, Proceedings. A. Kaul et al., eds. Berlin (West). 1984.

39. Nagataki S., *Overview Proposal from Nagasaki.* In: Nagasaki Symposium: Radiation Human Health. Amsterdam, 1996. pp. 11-18.

40. Gusev B.I., *Medical-Demographic Consequences of Irradiating the Population of Several Districts in the Semipalatinsk Province Due to Nuclear Weapons Testing.* Doctorate dissertation. Almaty, 1994.

41. Katon H. and Shimizu, Y., *Effects of A-Bomb Radiation on the Human Body* (cancer mortality rates in atomic bomb survivors). In: Effects of A-bomb Radiation on the Human Body. Shigenatsu, I., ed. Bunkodo Co, Tokyo, 1995. pp. 26-38.

42. Mabuchi K. and Kusumi S., *Leukemia.* In: Effects of A-bomb Radiation on the Human Body. Shigenatsu, I., ed. Bunkodo Co, Tokyo, 1995. pp. 26-38 [sic].

43. Noma K., *Endocrine and Metabolic Diseases.* Thyroid diseases. In: Effects of A-bomb Radiation on the Human Body. Shigenatsu, I., ed. Bunkodo Co, Tokyo, 1995. pp.128-136.

44. Rallison M.L., *Thyroid Neoplasia from Fallout Near the Nevada Test Site.* In : Nagasaki Symposium: Radiation and Human Health. Nagasaki, S. Yamashita, eds. Amsterdam, 1996. pp. 147-154.

45. Ezaki H., *Thyroid Cancer.* In: Effects of A-bomb radiation on the Human Body. Shigenatsu, I., ed. Bunkodo Co, Tokyo, 1995. pp. 70-79.

46. Sasakin H., *Lung Cancer.* In: Effects of A-bomb Radiation on the Human Body. Shigenatsu, I., ed. Bunkodo Co, Tokyo, 1995. pp. 62-69.

47. Mokunaga M., *Breast Cancer.* In: Effects of A-bomb Radiation on the Human Body. Shigenatsu, I., ed. Bunkodo Co, Tokyo, 1995. pp. 99-105.

48. Darby S.C., *Mortality of Patients Treated with X-Irradiation for Ankylosing Spondylitis.* IARC/DREZ.-LYON. 1989, p. 372.

49. Shimaoka K. and Akiba S., *Malignancies in Atomic Bomb Survivors in Hiroshima and Nagasaki.* Nuclear Medicine and Allied Sciences. 1990. Vol. 3, No. 4, pp. 254-259.

50. Greenstock C.L., *Radiation-Induced Aging and Induction and Promotion of Biological Damage.* Free Radical Aging and Degenerative Diseases. New York, 1986. pp. 197-219.

51. Denni I.A., *Mortality and Cancer Incidence in UK Participants in UK Atmospheric Nuclear Weapons Tests and Experimental Programs.* Rad. Prof. Bull. 1988. No. 90, pp. 4-7.

52. Baisagalov G.D. and Bolotnikova M.G., *Malignant Neoplasms in Circulatory and Lymphatic Tissues in Personnel of the First Atomic Industry Enterprise.* Issues of Oncology, 1991. Vol. 37, No. 5, pp. 553-559.

53. Kato H. and Schull W.I., *Studies of the Mortality of A-Bomb Survivors.* Rad. Res. 1982. Vol. 90, pp. 395-432.

54. Chlachierini R.P., *Iodine-131 Exposures and Neoplasms.* Rad. Res. 1990. Vol. 124, No. 3. pp. 349-360.

55. Iones R.R., *Radiation, Cancer Risk, and the New Dosimetry.* Lancet. 1987. No. 8568, p. 1143.

56. Storer I.B., *Radiation Carcinogenesis.* In: Becker F.E., ed. Cancer: A Comprehensive Treatise. 2nd ed. New York, Plenum Press. 1982. Vol. 1, pp. 629-659.

57. Mielne R., *Pathologists Block Research into Cancer and Radioactivity.* New Science 1989. Vol. 121, No. 1652, p. 26.

58. Raloff I., *Study Upgrades Radiation Risk to Humans.* Science News. 1989. Vol. 136, No. 26-27. pp. 404-408.

59. Miller R.W. and Boice I.D., *Radiogenic Cancer After Prenatal or Childhood Exposure.* Radiation Carcinogenesis. New York. e.a., 1987. pp. 379-386.

60. Ishimaru M., Ishimaru T., Mikani M., and Matsunaga M., *Multiple Myeloma Among Atomic Bomb Survivors in Hiroshima and Nagasaki,* 1950-76:Relationship to Radiation Dose Absorbed by Marrow. J. Nat. Cancer Inst.1982. Vol. 69, No. 2, p. 323.

61. Ishimaru M., Ohkita T., Ishimuru T., *Cancer in Atomic Bomb Survivors.* New York, 1986.

62. Muirhead C.R., *Reduction of Radiation-Induced Cancer Risks Across Time and Populations.* Radiation Professional Dosimetry. 1991. Vol. 36. No. 24. pp. 321-326.

APPENDIX A

Tables of Contamination Data after Each Test

December 28, 1966

Initial Data:
$q = 100$ kt
$V = 45$ km/hr
$H_{burst} = 150$ m
$h_{cloud} = 9.44$ km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	1.4	1.24	1.02
Time of arrival of cloud, hr	21.3	22.2	23.7
Radiation time of cloud, hr	7.03	7.32	7.79
Accepted time when cloud ceases radiation, hr	28.3	29.5	31.5
Dose from cloud, mGy	0.141	0.124	0.100
Dose from fallout, mGy	6.20	5.53	4.61
Dose to population, mGy	4.07	3.63	3.03
Total concentration of radionuclides in air, Bq/l	75.85	64.91	49.3
Concentration of I-131, Bq/l	3.07	2.80	2.37
Concentration of I-133, Bq/l	33.02	29.2	23.1
Concentration of I-135, Bq/l	14.9	12.0	8.35
Concentration of Cs-137, Bq/l	0.0685	0.0644	0.0572
Concentration of Sr-90, Bq/l	0.0678	0.0637	0.0565
Total surface soil contamination, Bq/m^2	4.25E+6	3.62E+6	2.75E+6
Contamination from I-131, Bq/m^2	1.72E+5	1.56E+5	1.32E+5
Contamination from I-133, Bq/m^2	1.85E+6	1.63E+6	1.29E+6
Contamination from I-135, Bq/m^2	8.34E+5	6.69E+5	4.66E+5
Contamination from Cs-137, Bq/m^2	3.84E+3	3.59E+3	3.19E+3
Contamination from Sr-90, Bq/m^2	3.80E+3	3.55E+3	3.15E+3
Contamination of vegetation:			
I-131, Bq/kg	1.03E+5	9.36E+4	7.92E+4
I-133, Bq/kg	1.11E+6	9.78E+5	7.74E+5
I-135, Bq/kg	5.00E+5	4.01E+5	2.80E+5
Cs-137, Bq/kg	2.30E+3	2.15E+3	1.91E+3
Sr-90, Bq/kg	2.28E+3	2.13E+3	1.89E+3
Maximum activity in milk:			
I-131, Bq/l	1.27E+4	1.41E+4	1.21E+4
I-133, Bq/l	1.58E+5	1.76E+5	1.53E+5
I-135, Bq/l	7.36E+5	8.15E+5	6.96E+5
Cs-137, Bq/l	638	725	643
Sr-90, Bq/l	66.4	75.3	66.7

June 17, 1967

Initial Data:
q = 2000 kt
V = 40 km/hr
H_{burst} = 100 m
h_{cloud} = 17.02 km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	48.5	42.9	35.8
Time of arrival of cloud, hr	24.0	25.0	26.7
Radiation time of cloud, hr	8.31	8.63	9.16
Accepted time when cloud ceases radiation, hr	32.3	33.6	35.8
Dose from cloud, mGy	4.33	3.81	3.52
Dose from fallout, mGy	225	196	166
Dose to population, mGy	143	129	109
Total concentration of radionuclides in air, Bq/l	2930	2070	49.3
Concentration of I-131, Bq/l	86.8	80.0	2.37
Concentration of I-133, Bq/l	831.3	735.9	23.1
Concentration of I-135, Bq/l	281.6	228.5	8.35
Concentration of Cs-137, Bq/l	1.459	1.388	0.0572
Concentration of Sr-90, Bq/l	1.448	1.381	0.0565
Total surface soil contamination, Bq/m^2	1.78E+8	1.07E+8	8.27E+7
Contamination from I-131, Bq/m^2	4.71E+6	4.13E+6	3.54E+6
Contamination from I-133, Bq/m^2	5.72E+7	3.82E+7	3.04E+7
Contamination from I-135, Bq/m^2	3.48E+7	1.18E+7	8.06E+6
Contamination from Cs-137, Bq/m^2	7.67E+4	7.17E+4	6.46E+4
Contamination from Sr-90, Bq/m^2	7.61E+4	7.13E+4	6.41E+4
Contamination of vegetation:			
I-131, Bq/kg	2.82E+6	2.48E+6	2.12E+6
I-133, Bq/kg	3.42E+7	2.28E+7	1.82E+7
I-135, Bq/kg	2.08E+7	7.08E+6	4.84E+6
Cs-137, Bq/kg	4.60E+4	4.31E+4	3.88E+4
Sr-90, Bq/kg	4.60E+4	4.31E+4	3.85E+4
Maximum activity in milk:			
I-131, Bq/l	2.42E+5	2.23E+5	2.68E+5
I-133, Bq/l	3.05E+6	2.77E+6	3.36E+6
I-135, Bq/l	1.41E+7	1.29E+7	1.56E+7
Cs-137, Bq/l	9080	8510	10,700
Sr-90, Bq/l	949	889	1120

January 7, 1972

Initial Data:
q = 20 kt
V = 48 km/hr
H_{burst} = 100 m
h_{cloud} = 6.46 km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	0.20	0.18	0.14
Time of arrival of cloud, hr	20.0	20.8	22.2
Radiation time of cloud, hr	6.51	6.78	7.22
Accepted time when cloud ceases radiation, hr	26.5	27.6	29.4
Dose from cloud, mGy	0.0202	0.0177	0.0142
Dose from fallout, mGy	0.874	0.776	0.643
Dose to population, mGy	0.575	0.510	0.422
Total concentration of radionuclides in air, Bq/l	10.2	7.34	5.55
Concentration of I-131, Bq/l	0.452	0.349	0.293
Concentration of I-133, Bq/l	5.116	3.831	3.051
Concentration of I-135, Bq/l	2.623	1.821	1.282
Concentration of Cs-137, Bq/l	0.0122	9.78E-3	8.56E-3
Concentration of Sr-90, Bq/l	0.0121	9.61E-3	8.44E-3
Total surface soil contamination, Bq/m^2	6.29E+5	5.17E+5	3.89E+5
Contamination from I-131, Bq/m^2	2.81E+4	2.46E+4	2.05E+4
Contamination from I-133, Bq/m^2	3.16E+5	2.70E+5	2.14E+5
Contamination from I-135, Bq/m^2	1.62E+5	1.28E+5	8.94E+4
Contamination from Cs-137, Bq/m^2	7.54E+2	6.85E+2	6.03E+2
Contamination from Sr-90, Bq/m^2	7.44E+2	6.76E+2	5.91E+2
Contamination of vegetation:			
I-131, Bq/kg	1.68E+4	1.47E+4	1.23E+4
I-133, Bq/kg	1.90E+5	1.62E+5	1.28E+5
I-135, Bq/kg	9.72E+4	7.68E+4	5.36E+4
Cs-137, Bq/kg	4.52E+2	4.11E+2	3.60E+2
Sr-90, Bq/kg	4.46E+2	4.06E+2	3.55E+2
Maximum activity in milk:			
I-131, Bq/l	2.48E+3	2.19E+3	1.84E+3
I-133, Bq/l	3.10E+5	2.75E+4	2.31E+4
I-135, Bq/l	1.44E+5	1.28E+5	1.07E+5
Cs-137, Bq/l	152	138	121
Sr-90, Bq/l	15.7	14.3	12.5

March 18, 1972

Initial Data:
q = 20 kt
V = 45 km/hr
H_{burst} = 1000 m
h_{cloud} = 7.74 km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	0.20	0.17	0.14
Time of arrival of cloud, hr	22.9	23.8	25.4
Radiation time of cloud, hr	7.44	7.75	8.25
Accepted time when cloud ceases radiation, hr	30.3	31.6	33.7
Dose from cloud, mGy	0.0194	0.0170	0.0137
Dose from fallout, mGy	0.885	0.786	0.651
Dose to population, mGy	0.581	0.516	0.427
Total concentration of radionuclides in air, Bq/l	10.4	8.02	6.08
Concentration of I-131, Bq/l	0.527	0.432	0.363
Concentration of I-133, Bq/l	5.349	4.216	3.321
Concentration of I-135, Bq/l	2.095	1.511	1.032
Concentration of Cs-137, Bq/l	0.0153	0.0119	0.0104
Concentration of Sr-90, Bq/l	0.0151	0.0117	0.0102
Total surface soil contamination, Bq/m^2	5.96E+5	4.68E+5	3.55E+5
Contamination from I-131, Bq/m^2	3.02E+4	2.52E+4	2.12E+4
Contamination from I-133, Bq/m^2	3.07E+5	2.46E+5	1.94E+5
Contamination from I-135, Bq/m^2	1.21E+5	8.81E+4	6.03E+4
Contamination from Cs-137, Bq/m^2	8.82E+2	6.92E+2	6.13E+2
Contamination from Sr-90, Bq/m^2	8.69E+2	6.83E+2	6.01E+2
Contamination of vegetation:			
I-131, Bq/kg	1.81E+4	1.51E+4	1.27E+4
I-133, Bq/kg	1.51E+5	1.48E+5	1.16E+5
I-135, Bq/kg	7.22E+4	5.29E+4	3.64E+4
Cs-137, Bq/kg	5.29E+2	4.15E+2	3.66E+2
Sr-90, Bq/kg	5.22E+2	4.11E+2	3.61E+2
Maximum activity in milk:			
I-131, Bq/l	2.74E+3	2.29E+3	1.93E+3
I-133, Bq/l	3.43E+4	2.86E+4	2.42E+4
I-135, Bq/l	1.59E+5	1.33E+5	1.12E+5
Cs-137, Bq/l	178	139	123
Sr-90, Bq/l	18.3	14.5	12.7

June 27, 1973

Initial Data:
q = 2.5 MT
V = 47 km/hr
H_{burst} = 1000 m
h_{cloud} = 18.7 km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	77.5	69.4	58.3
Time of arrival of cloud, hr	20.4	21.3	22.7
Radiation time of cloud, hr	7.11	7.39	7.84
Accepted time when cloud ceases radiation, hr	27.5	28.7	30.5
Dose from cloud, mGy	8.17	7.24	5.99
Dose from fallout, mGy	341	308	262
Dose to population, mGy	224	202	172
Total concentration of radionuclides in air, Bq/l	4,470	4,040	3,150
Concentration of I-131, Bq/l	121.4	113.7	98.5
Concentration of I-133, Bq/l	1339	121.5	995.1
Concentration of I-135, Bq/l	637.1	531.2	384.3
Concentration of Cs-137, Bq/l	1.773	1.653	1.511
Concentration of Sr-90, Bq/l	1.770	1.651	1.502
Total surface soil contamination, Bq/m^2	2.33E+8	2.09E+8	1.64E+8
Contamination from I-131, Bq/m^2	6.33E+6	5.89E+6	5.13E+6
Contamination from I-133, Bq/m^2	6.98E+7	6.29E+7	5.18E+7
Contamination from I-135, Bq/m^2	3.32E+7	3.75E+7	2.03E+7
Contamination from Cs-137, Bq/m^2	9.24E+4	8.55E+4	7.83E+4
Contamination from Sr-90, Bq/m^2	9.20E+4	8.52E+4	7.79E+4
Contamination of vegetation:			
I-131, Bq/kg	3.80E+6	3.53E+6	3.08E+6
I-133, Bq/kg	4.19E+7	3.77E+7	3.11E+7
I-135, Bq/kg	1.99E+7	1.65E+7	1.20E+7
Cs-137, Bq/kg	5.54E+4	5.13E+4	4.71E+4
Sr-90, Bq/kg	5.52E+4	5.11E+4	1.89E+4
Maximum activity in milk:			
I-131, Bq/l	3.32E+5	3.11E+5	3.11E+5
I-133, Bq/l	4.17E+6	3.91E+6	3.91E+6
I-135, Bq/l	1.95E+7	1.81E+7	1.81E+7
Cs-137, Bq/l	11,200	10,100	9,310
Sr-90, Bq/l	1,140	1,060	972

January 23, 1976

Initial Data:
q = 10 MT
V = 44 km/hr
H_{burst} = (underground, with ejection of material)
h_{cloud} = 5.86 km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	0.07	0.06	0.05
Time of arrival of cloud, hr	21.8	22.7	24.2
Radiation time of cloud, hr	7.08	7.37	7.85
Accepted time when cloud ceases radiation, hr	28.9	30.1	32.1
Dose from cloud, mGy	0.007	0.006	0.005
Dose from fallout, mGy	0.317	0.280	0.230
Dose to population, mGy	0.208	0.184	0.151
Total concentration of radionuclides in air, Bq/l	3.34	2.79	2.10
Concentration of I-131, Bq/l	0.181	0.161	0.135
Concentration of I-133, Bq/l	1.912	1.647	1.297
Concentration of I-135, Bq/l	0.827	0.654	0.449
Concentration of Cs-137, Bq/l	0.00555	0.00510	0.00446
Concentration of Sr-90, Bq/l	0.00546	0.00502	0.00439
Total surface soil contamination, Bq/m^2	2.63E+5	2.31E+5	1.88E+5
Contamination from I-131, Bq/m^2	1.16E+4	1.04E+4	8.75E+3
Contamination from I-133, Bq/m^2	1.42E+5	1.27E+5	1.07E+5
Contamination from I-135, Bq/m^2	8.65E+4	7.75E+4	6.57E+4
Contamination from Cs-137, Bq/m^2	3.50E+2	3.22E+2	2.82E+2
Contamination from Sr-90, Bq/m^2	3.45E+2	3.20E+2	2.77E+2
Contamination of vegetation:			
I-131, Bq/kg	4.35E+2	3.90E+2	3.28E+2
I-133, Bq/kg	5.33E+3	4.76E+3	4.01E+3
I-135, Bq/kg	3.24E+3	2.91E+3	2.46E+3
Cs-137, Bq/kg	1.31E+1	1.21E+1	1.06E+1
Sr-90, Bq/kg	1.29E+1	1.20E+1	1.03E+1
Maximum activity in milk:			
I-131, Bq/l	1.03E+3	9.18E+2	7.72E+2
I-133, Bq/l	1.28E+4	1.15E+4	9.67E+3
I-135, Bq/l	5.96E+4	5.34E+4	4.49E+4
Cs-137, Bq/l	70.6	64.9	56.8
Sr-90, Bq/l	7.29	6.71	5.87

September 26, 1976

Initial Data:
q = 20 kt
V = 45 km/hr
H_{burst} = 30 m
h_{cloud} = 6.74 km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	0.18	0.16	0.13
Time of arrival of cloud, hr	21.3	22.2	23.7
Radiation time of cloud, hr	6.95	7.23	7.70
Accepted time when cloud ceases radiation, hr	28.3	29.4	31.4
Dose from cloud, mGy	0.0180	0.0157	0.0126
Dose from fallout, mGy	0.799	0.708	0.585
Dose to population, mGy	0.525	0.465	0.384
Total concentration of radionuclides in air, Bq/l	9.1	7.7	5.05
Concentration of I-131, Bq/l	0.440	0.397	0.293
Concentration of I-133, Bq/l	4.723	4.151	2.841
Concentration of I-135, Bq/l	2.151	1.732	1.042
Concentration of Cs-137, Bq/l	0.0123	0.0113	0.00867
Concentration of Sr-90, Bq/l	0.0121	0.0112	0.00854
Total surface soil contamination, Bq/m^2	5.50E+5	4.64E+5	3.48E+5
Contamination from I-131, Bq/m^2	2.68E+4	2.39E+4	2.02E+4
Contamination from I-133, Bq/m^2	2.88E+5	2.50E+5	1.96E+5
Contamination from I-135, Bq/m^2	1.30E+5	1.04E+5	7.13E+4
Contamination from Cs-137, Bq/m^2	7.43E+2	6.83E+2	5.98E+2
Contamination from Sr-90, Bq/m^2	7.33E+2	6.73E+2	5.89E+2
Contamination of vegetation:			
I-131, Bq/kg	1.61E+4	1.43E+4	1.21E+4
I-133, Bq/kg	1.73E+5	1.50E+5	1.18E+5
I-135, Bq/kg	1.30E+5	6.24E+4	4.28E+4
Cs-137, Bq/kg	4.46E+2	4.10E+2	3.60E+2
Sr-90, Bq/kg	4.39E+2	4.01E+2	3.53E+2
Maximum activity in milk:			
I-131, Bq/l	2.40E+3	2.15E+3	1.82E+3
I-133, Bq/l	3.01E+4	2.71E+4	2.27E+4
I-135, Bq/l	1.39E+5	1.25E+5	1.06E+5
Cs-137, Bq/l	150	138	121
Sr-90, Bq/l	15.5	14.3	12.5

September 17, 1977

Initial Data:
$q = 20$ kt
$V = 40$ km/hr
$H_{burst} = 30$ m
$h_{cloud} = 6.74$ km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	0.15	0.13	0.11
Time of arrival of cloud, hr	24.0	25.0	26.7
Radiation time of cloud, hr	7.82	8.14	10.0
Accepted time when cloud ceases radiation, hr	31.8	33.1	36.7
Dose from cloud, mGy	0.0149	0.0129	0.0104
Dose from fallout, mGy	0.692	0.612	0.504
Dose to population, mGy	0.454	0.401	0.330
Total concentration of radionuclides in air, Bq/l	6.67	5.64	3.54
Concentration of I-131, Bq/l	0.391	0.353	0.256
Concentration of I-133, Bq/l	3.759	3.321	2.151
Concentration of I-135, Bq/l	1.341	1.072	0.539
Concentration of Cs-137, Bq/l	0.0118	0.0110	0.00504
Concentration of Sr-90, Bq/l	0.0116	0.0108	0.00494
Total surface soil contamination, Bq/m^2	4.04E+5	3.40E+5	2.45E+5
Contamination from I-131, Bq/m^2	2.37E+4	2.13E+4	1.77E+4
Contamination from I-133, Bq/m^2	2.30E+5	1.99E+5	1.49E+5
Contamination from I-135, Bq/m^2	8.14E+4	6.42E+4	3.73E+4
Contamination from Cs-137, Bq/m^2	7.16E+2	6.61E+2	5.80E+2
Contamination from Sr-90, Bq/m^2	7.05E+2	6.50E+2	5.71E+2
Contamination of vegetation:			
I-131, Bq/kg	1.42E+4	1.27E+4	1.06E+4
I-133, Bq/kg	1.38E+5	1.19E+5	8.94E+4
I-135, Bq/kg	4.88E+4	3.85E+4	2.24E+4
Cs-137, Bq/kg	4.30E+2	3.97E+2	3.49E+2
Sr-90, Bq/kg	4.23E+2	3.90E+2	3.42E+2
Maximum activity in milk:	2.15E+3	1.94E+3	1.64E+3
I-131, Bq/l	2.69E+4	2.44E+4	2.04E+4
I-133, Bq/l	1.25E+5	1.12E+5	9.51E+4
I-135, Bq/l	145	133	117
Cs-137, Bq/l	15.0	13.8	12.1
Sr-90, Bq/l			

March 15, 1978

Initial Data:
q = 20 kt
V = 45 km/hr
H_{burst} = 30 m
h_{cloud} = 6.77 km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	0.18	0.16	0.13
Time of arrival of cloud, hr	21.3	22.2	23.7
Radiation time of cloud, hr	6.94	7.23	7.72
Accepted time when cloud ceases radiation, hr	28.2	29.4	31.4
Dose from cloud, mGy	0.0180	0.0157	0.0126
Dose from fallout, mGy	0.799	0.708	0.585
Dose to population, mGy	0.525	0.465	0.384
Total concentration of radionuclides in air, Bq/l	9.21	7.79	5.83
Concentration of I-131, Bq/l	0.442	0.398	0.336
Concentration of I-133, Bq/l	4.781	4.161	3.289
Concentration of I-135, Bq/l	2.173	1.752	1.193
Concentration of Cs-137, Bq/l	0.0122	0.0114	0.00995
Concentration of Sr-90, Bq/l	0.0120	0.0112	0.00980
Total surface soil contamination, Bq/m^2	5.60E+5	4.67E+5	3.51E+5
Contamination from I-131, Bq/m^2	2.69E+4	2.39E+4	2.02E+4
Contamination from I-133, Bq/m^2	2.91E+5	2.50E+5	1.98E+5
Contamination from I-135, Bq/m^2	1.32E+5	1.05E+5	7.18E+4
Contamination from Cs-137, Bq/m^2	7.41E+2	6.80E+2	5.99E+2
Contamination from Sr-90, Bq/m^2	7.31E+2	6.70E+2	5.90E+2
Contamination of vegetation:			
I-131, Bq/kg	1.61E+4	1.43E+4	1.21E+4
I-133, Bq/kg	1.75E+5	1.51E+5	1.18E+5
I-135, Bq/kg	7.92E+4	6.30E+4	4.31E+4
Cs-137, Bq/kg	4.45E+2	4.08E+2	3.60E+2
Sr-90, Bq/kg	4.39E+2	4.02E+2	3.54E+2
Maximum activity in milk:			
I-131, Bq/l	2.26E+3	2.15E+3	1.82E+3
I-133, Bq/l	3.00E+4	2.70E+4	2.28E+4
I-135, Bq/l	1.41E+5	1.26E+5	1.06E+5
Cs-137, Bq/l	149	137	121
Sr-90, Bq/l	15.5	14.2	12.5

December 14, 1978

Initial Data:
q = 20 kt
V = 51 km/hr
H_{burst} = 30 m
h_{cloud} = 6.74 km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	0.21	0.19	0.16
Time of arrival of cloud, hr	18.8	19.6	20.9
Radiation time of cloud, hr	6.12	6.38	6.82
Accepted time when cloud ceases radiation, hr	24.9	26.0	27.7
Dose from cloud, mGy	0.0219	0.0191	0.0155
Dose from fallout, mGy	0.924	0.821	0.681
Dose to population, mGy	0.608	0.540	0.448
Total concentration of radionuclides in air, Bq/l	12.6	10.5	7.98
Concentration of I-131, Bq/l	0.494	0.443	0.373
Concentration of I-133, Bq/l	5.951	5.111	4.123
Concentration of I-135, Bq/l	3.323	2.712	1.923
Concentration of Cs-137, Bq/l	0.0125	0.0115	0.00610
Concentration of Sr-90, Bq/l	0.0123	0.0114	0.00601
Total surface soil contamination, Bq/m^2	7.62E+5	6.35E+5	4.83E+5
Contamination from I-131, Bq/m^2	2.99E+4	2.68E+4	2.26E+4
Contamination from I-133, Bq/m^2	3.60E+5	3.09E+5	2.48E+5
Contamination from I-135, Bq/m^2	2.01E+5	1.64E+5	1.16E+5
Contamination from Cs-137, Bq/m^2	7.55E+2	6.96E+2	6.15E+2
Contamination from Sr-90, Bq/m^2	7.45E+2	6.87E+2	6.06E+2
Contamination of vegetation:			
I-131, Bq/kg	1.79E+4	1.61E+4	1.36E+4
I-133, Bq/kg	2.16E+5	1.85E+5	1.49E+5
I-135, Bq/kg	1.21E+5	9.84E+4	6.96E+4
Cs-137, Bq/kg	4.53E+2	4.18E+2	3.69E+2
Sr-90, Bq/kg	4.47E+2	4.12E+2	3.64E+2
Maximum activity in milk:			
I-131, Bq/l	2.64E+3	2.38E+3	2.02E+3
I-133, Bq/l	3.13E+4	2.98E+4	2.53E+4
I-135, Bq/l	1.54E+5	1.38E+5	1.17E+5
Cs-137, Bq/l	152	140	124
Sr-90, Bq/l	15.8	14.6	12.8

November 12, 1981

Initial Data:
q = 20 kt
V = 50 km/hr
H_{burst} = 30 m
h_{cloud} = 6.74 km

	Makanchy	Urdzhar	Taskesken
Distance from explosion epicenter, km	960	1000	1066
Dose rate at Zero hour+24, mR/hr	0.21	0.18	0.15
Time of arrival of cloud, hr	19.2	20.0	21.3
Radiation time of cloud, hr	6.25	6.51	6.93
Accepted time when cloud ceases radiation, hr	25.5	26.5	28.2
Dose from cloud, mGy	0.0212	0.0186	0.0150
Dose from fallout, mGy	0.903	0.802	0.665
Dose to population, mGy	0.594	0.527	0.437
Total concentration of radionuclides in air, Bq/l	11.9	8.16	7.63
Concentration of I-131, Bq/l	0.484	0.354	0.367
Concentration of I-133, Bq/l	5.681	4.021	3.973
Concentration of I-135, Bq/l	3.113	2.052	1.823
Concentration of Cs-137, Bq/l	0.0124	0.00933	0.0102
Concentration of Sr-90, Bq/l	0.0123	0.00921	0.0100
Total surface soil contamination, Bq/m^2	7.19E+5	6.05E+5	4.61E+5
Contamination from I-131, Bq/m^2	2.93E+4	2.63E+4	2.22E+4
Contamination from I-133, Bq/m^2	3.43E+5	2.98E+5	2.40E+5
Contamination from I-135, Bq/m^2	1.88E+5	1.52E+5	1.09E+4
Contamination from Cs-137, Bq/m^2	7.51E+2	6.92E+2	6.13E+2
Contamination from Sr-90, Bq/m^2	7.41E+2	6.83E+2	6.05E+2
Contamination of vegetation:			
I-131, Bq/kg	1.76E+4	1.58E+4	1.33E+4
I-133, Bq/kg	2.06E+5	1.79E+5	1.44E+5
I-135, Bq/kg	1.13E+5	9.12E+4	6.54E+4
Cs-137, Bq/kg	4.15E+2	4.14E+2	3.68E+2
Sr-90, Bq/kg	4.44E+2	4.11E+2	3.63E+2
Maximum activity in milk:			
I-131, Bq/l	2.60E+3	2.34E+3	1.99E+3
I-133, Bq/l	3.25E+4	2.93E+4	2.49E+4
I-135, Bq/l	1.51E+5	1.06E+5	1.20E+5
Cs-137, Bq/l	151	139	124
Sr-90, Bq/l	15.7	14.5	12.8

APPENDIX B

Specific Activity in Samples of Soil, Vegetation, and Milk from Each District

Results From Samples Taken in 1998

Makanchy Soil

Sample no., 0-1 cm layer	Sampling date	Total activity on sampling date, Bq/kg	Specific activity of radionuclides on sampling date, Bq/kg								
			Cs-137	Sr-90	I-131	I-133	I-135	Sr-89	Zr-95	Te-132	Ba-140
---	1963	1117	16.5	18.5	--	--	--	--	--	--	--
10100	1 Apr 1967	19,300	240	238	--	--	--	5130	385	--	53.6
10101	"	22,900	238	236	--	--	--	4890	411	--	49.8
10102	"	17,900	247	229	--	--	--	5020	322	--	50.1
10103	"	18,400	221	235	--	--	--	4550	309	--	52.2
10104	"	19,000	243	240	--	--	--	4760	401	--	48.7
12341	25 Jun 1967	1,191,000	4850	4720	143,000	4600	--	431,000	36,900	145,000	272,000
12342	"	2,080,000	4900	4710	154,000	4680	--	397,000	37,100	122,000	244,000
12343	"	975,000	4620	5130	123,000	4820	--	408,000	29,800	109,000	283,000
12344	"	756,000	5120	4320	168,000	4310	--	457,000	40,100	188,000	211,000
12345	"	1,920,000	5090	4700	140,000	4510	--	432,000	34,100	134,000	301,000
15111	10 Apr 1972	1140	55.5	54.1	284	--	--	2790	162	39.6	756
15112	"	987	52.2	50.6	277	--	--	2450	157	35.5	677
15113	"	1030	34.3	48.3	283	--	--	2310	163	40.9	698
15114	"	1110	61.1	60.0	294	--	--	2960	158	35.7	801
15115	"	976	42.6	54.0	301	--	--	2230	160	41.1	744
19411	10 Jul 1973	868,000	5780	5750	132,000	139	--	505,000	54,500	70,100	285,000
19412	"	793,000	5390	6010	151,000	161	--	499,000	51,100	65,500	277,000
19413	"	831,000	5910	5820	122,000	137	--	513,000	52,300	71,200	293,000
19414	"	895,000	5630	5490	163,000	158	--	478,000	60,100	67,800	268,000
19415	"	874,000	6040	5930	114,000	142	--	466,000	53,100	69,100	281,000
30104	30 Sep 1976	7920	46.5	45.8	1210	744	--	3440	140	1750	1890
30105	"	8840	45.5	50.1	1110	788	--	3210	137	1870	1770
30106	"	8110	50.0	44.6	1210	754	--	3560	154	1610	2010
30107	"	7430	41.1	43.2	1540	768	--	3080	122	1550	1460
30108	"	7900	47.0	46.0	1010	734	--	3770	128	1780	1580
35200	30 Sep 1977	1790	44.8	44.1	484	--	--	2870	107	227	1040
35201	"	1580	44.3	44.5	472	--	--	2550	100	212	1110
35202	"	1810	44.5	41.6	464	--	--	2730	99.7	233	972
35203	"	1720	46.9	44.1	504	--	--	2760	102	223	899
35204	"	1640	45.0	39.8	501	--	--	2820	86.5	230	1170
35941	20 Mar 1978	8020	46.3	45.7	1090	339	--	3400	139	1410	1790
35942	"	8100	45.5	42.8	1110	333	--	3110	122	1520	1660
35943	"	7870	46.7	41.7	1070	364	--	3520	154	1330	1820
35944	"	8110	47.1	44.2	990	329	--	3410	133	1390	1700
35945	"	7920	46.0	46.0	1290	351	--	3290	140	1440	1870
37225	15 Mar 1979	225	147	146	--	--	--	--	--	--	--
37226	"	217	146	145	--	--	--	--	--	--	--
37227	"	228	147	147	--	--	--	--	--	--	--
37228	"	235	146	146	--	--	--	--	--	--	--
37229	"	241	147	144	--	--	--	--	--	--	--
41562	16 Nov 1981	12,900	46.9	46.3	1410	1960	7.03	3620	161	1930	2070
41563	"	11,800	47.6	46.6	1010	2010	6.75	3580	157	1770	2000
41564	"	14,300	48.7	44.1	1720	1770	7.11	3700	160	2010	1980
41565	"	12,500	44.8	43.9	1510	1560	7.24	3610	144	1880	1890
41566	"	11,900	47.0	44.7	1230	2160	6.93	3550	172	1910	2110

Urdzhar Soil

Sample no., 0-1 cm layer	Sampling date	Total activity on sampling date, Bq/kg	Specific activity of radionuclides on sampling date, Bq/kg								
			Cs-137	Sr-90	I-131	I-133	I-135	Sr-89	Zr-95	Te-132	Ba-140
---	1963	994	36.9	--	--	--	--	--	--	--	--
10105	1 Apr 1967	17,600	224	221	--	--	--	4610	328	--	47.1
10106	"	17,200	239	236	--	--	--	4050	291	--	50.2
10107	"	16,900	198	184	--	--	--	4110	302	--	44.6
10108	"	17,400	204	269	--	--	--	5010	371	--	42.1
10109	"	18,000	225	220	--	--	--	3890	288	--	48.7
12356	25 Jun 1967	1,170,000	4480	4460	131,000	4110	--	390,000	31,800	128,000	241,000
12357	"	1,190,000	4340	4610	122,000	4070	--	377,000	31,100	97,600	222,000
12358	"	986,000	4590	4530	123,000	4230	--	405,000	32,000	118,000	253,000
12359	"	643,000	4610	4510	139,000	4160	--	356,000	30,900	98,700	205,000
12360	"	1,460,000	4770	4380	134,000	4000	--	368,000	31,500	144,000	212,000
15126	10 Apr 1972	1050	44.3	42.7	237	--	--	2550	111	35.5	681
15127	"	895	44.1	42.1	228	--	--	2530	123	34.7	677
15128	"	1240	39.8	42.9	254	--	--	2790	97.7	40.8	701
15129	"	965	46.3	38.7	212	--	--	2010	123	32.2	655
15130	"	1010	44.0	43.1	207	--	--	2380	86.6	33.8	679
19426	10 Jul 1973	821,000	5340	5330	120,000	125	--	468,000	48,800	63,900	260,000
19427	"	793,000	5300	5310	135,000	123	--	456,000	43,500	61,100	244,000
19428	"	824,000	5460	4830	98,700	105	--	421,000	47,800	59,800	273,000
19429	"	815,000	4980	5120	119,000	168	--	472,000	45,500	62,300	238,000
19430	"	833,000	5220	5460	123,000	182	--	444,000	46,500	64,100	255,000
30119	30 Sep 1976	6950	42.7	42.1	1060	646	--	3140	123	1560	1700
30120	"	6840	34.4	44.1	1010	638	--	3090	109	1640	1730
30121	"	7130	30.2	40.1	1210	624	--	3240	133	1430	1560
30122	"	6970	43.9	39.4	980	668	--	3660	122	1520	1490
30123	"	6900	44.0	38.5	1030	704	--	2780	114	1600	1680
35215	30 Sep 1977	1580	41.3	40.6	435	--	--	2610	94.1	203	939
35216	"	1560	41.0	40.1	422	--	--	2440	92.6	198	864
35217	"	1220	37.2	40.0	414	--	--	2850	98.1	211	1000
35218	"	1120	41.1	42.2	394	--	--	2540	100	200	955
35219	"	1650	43.9	38.9	401	--	--	2770	91.1	201	877
35956	20 Mar 1978	7060	42.5	41.9	971	291	--	3100	121	1260	1610
35957	"	7010	42.1	41.2	801	233	--	2760	111	1220	1550
35958	"	6980	43.5	42.0	965	276	--	3000	132	1450	1740
35959	"	6730	41.1	39.9	982	309	--	2690	120	1080	1600
35960	"	7130	43.0	40.8	959	311	--	3170	109	1190	1490
37230	15 Mar 1979	197	143	142	--	--	--	--	--	--	--
37231	"	147	144	141	--	--	--	--	--	--	--
37232	"	201	142	139	--	--	--	--	--	--	--
37233	"	212	144	144	--	--	--	--	--	--	--
37234	"	181	141	143	--	--	--	--	--	--	--
41577	16 Nov 1981	1140	43.3	44.2	1310	1710	5.73	3310	143	1720	1860
41578	"	1090	42.1	40.1	1220	1570	6.03	3360	133	1660	1770
41579	"	1040	45.3	35.1	1300	1840	5.89	3220	154	1840	1900
41580	"	1120	39.3	43.2	998	1750	5.66	3190	145	1800	1550
41581	"	1110	41.1	42.7	1540	1690	5.23	3400	138	1700	2010

Taskesken Soil

Sample no., 0-1 cm Layer	Sampling date	Total activity on sampling date, Bq/kg	Specific activity of radionuclides on sampling date, Bq/kg								
			Cs-137	Sr-90	I-131	I-133	I-135	Sr-89	Zr-95	Te-132	Ba-140
---	1963	1080	14.7	17.4	--	--	--	--	--	--	--
10110	1 Apr 1967	14,500	199	197	--	--	--	3520	270	--	40.1
10111	"	16,100	209	199	--	--	--	3330	301	--	38.7
10112	"	14,200	197	181	--	--	--	3760	239	--	32.2
10113	"	13,800	201	204	--	--	--	3280	268	--	41.2
10114	"	15,000	200	200	--	--	--	4010	243	--	39.6
12371	25 Jun 1967	976,000	4040	4010	113,000	3250	--	345,000	26,000	112,000	208,000
12372	"	1,190,000	3980	3610	124,000	3160	--	309,000	24,300	87,700	212,000
12373	"	975,000	4110	4320	98,300	3670	--	377,000	28,900	93,200	178,000
12374	"	624,000	4260	3520	111,000	2950	--	321,000	26,100	108,000	155,000
12375	"	1,350,000	3940	3890	109,000	3220	--	355,000	27,000	111,000	196,000
15141	10 Apr 1972	803	38.1	37.6	199	--	--	2210	90.9	29.8	575
15142	"	781	37.7	36.5	187	--	--	2170	88.8	27.7	478
15143	"	911	36.9	40.9	209	--	--	2350	90.6	30.4	633
15144	"	821	40.8	38.4	211	--	--	2440	91.7	29.2	611
15145	"	815	38.0	38.0	175	--	--	2090	87.6	31.1	525
19441	10 Jul 1973	691,000	4890	4870	105,000	103	--	417,000	41,000	55,200	226,000
19442	"	701,000	4910	4970	103,000	95.6	--	397,000	42,100	53,300	211,000
19443	"	676,000	4560	5070	99,500	92.3	--	422,000	38,800	56,100	209,000
19444	"	693,000	5090	4620	98,700	101	--	412,000	37,600	55,500	243,000
19445	"	711,000	4870	4740	133,000	111	--	389,000	43,700	54,700	222,000
30134	30 Sep 1976	5680	37.4	36.6	895	506	--	2720	101	1310	1430
30135	"	5720	38.5	35.5	1100	588	--	2660	97.1	1250	1370
30136	"	5610	40.0	36.8	921	494	--	2810	98.6	1440	1540
30137	"	5530	35.6	37.2	854	508	--	2770	108	1210	1300
30138	"	5700	37.0	37.0	1010	485	--	2540	100	1420	1410
35230	30 Sep 1977	1290	36.3	35.7	361	--	--	2250	76.8	169	791
35231	"	1180	33.3	35.5	372	--	--	2110	72.4	144	767
35232	"	1310	36.8	36.4	346	--	--	2330	78.1	172	745
35233	"	1220	38.4	34.1	400	--	--	1990	72.3	159	811
35234	"	1040	36.5	36.0	361	--	--	2410	65.5	170	809
35971	20 Mar 1978	5740	33.7	33.6	821	231	--	2680	99.5	1060	1360
35972	"	5700	33.5	31.7	711	233	--	2470	99.1	1110	1220
35973	"	6070	36.8	32.1	817	264	--	2710	89.9	1000	1440
35974	"	5610	39.6	33.8	799	199	--	2590	99.7	989	1610
35975	"	5840	31.1	33.4	829	185	--	2650	99.3	877	1380
37235	15 Mar 1979	162	138	137	--	--	--	--	--	--	--
37236	"	161	140	136	--	--	--	--	--	--	--
37237	"	173	139	140	--	--	--	--	--	--	--
37238	"	152	136	135	--	--	--	--	--	--	--
37239	"	158	138	137	--	--	--	--	--	--	--
41592	16 Nov 1981	9350	33.8	33.7	1070	1370	4.13	2870	117	1450	1570
41593	"	9220	39.8	36.7	889	1280	4.34	2760	111	1330	1520
41594	"	9540	32.7	31.8	997	1340	3.95	2790	122	1520	1610
41595	"	8950	35.1	32.1	1110	1690	3.83	2910	109	1400	1580
41596	"	9150	33.4	32.6	1010	1080	4.11	2560	110	1440	1440

Makanchy Vegetation

Sample no.	Sampling date	Specific activity of radionuclides on sampling date, Bq/kg								
		Cs-137	Sr-90	I-131	I-133	I-135	Sr-89	Zr-95	Te-132	Ba-140
12346	25 Jun 1967	38,600	37,500	1,290,000	57,900	--	257,000	17,900	70,100	14,500
12347	"	36,100	35,500	989,000	56,600	--	255,000	16,900	66,600	12,400
12348	"	40,600	42,600	1,440,000	51,400	--	262,000	20,000	71,800	15,500
12349	"	39,200	38,700	1,310,000	57,900	--	238,000	15,700	67,100	13,900
12350	"	37,700	37,500	1,180,000	58,000	--	260,000	18,000	70,000	15,000
15116	10 Apr 1972	85.22	84.32	478	--	--	1690	23.22	9.10	145
15117	"	83.90	84.02	501	--	--	1550	22.40	8.73	133
15118	"	81.39	83.90	433	--	--	1620	20.95	9.12	167
15119	"	85.03	84.11	491	--	--	1740	21.81	7.99	151
15120	"	85.28	83.73	476	--	--	1700	23.09	9.24	150
19416	10 Jul 1973	41,100	40,900	1,020,000	2180	--	307,000	16,700	26,400	91,100
19417	"	40,000	41,200	1,340,000	2110	--	311,000	15,500	24,200	106,000
19418	"	42,800	37,900	976,000	2430	--	314,000	21,900	23,400	112,000
19419	"	39,100	40,100	987,000	2340	--	309,000	12,200	30,000	86,900
19420	"	40,700	42,700	1,000,000	2040	--	300,000	17,000	26,000	90,000
30109	30 Sep 1976	375	369	106,000	15,300	60.60	2100	71.61	1090	1010
30110	"	373	371	100,000	15,600	58.97	2090	70.93	1190	1020
30111	"	368	380	102,000	14,800	59.89	2120	69.89	1110	998
30112	"	373	359	111,000	14,200	60.42	1980	71.50	977	1110
30113	"	381	347	104,000	16,700	61.01	2000	72.04	1000	1000
35205	30 Sep 1977	214	211	2580	6.27	--	1750	33.01	86.3	336
35206	"	198	207	2420	6.18	--	1550	32.18	87.1	325
35207	"	235	213	2770	6.24	--	1690	33.50	85.9	327
35208	"	207	189	2380	5.87	--	1530	30.99	84.8	341
35209	"	211	201	2610	6.03	--	1800	33.10	86.0	340
35946	20 Mar 1978	314	310	8050	5090	--	2070	67.04	838	907
35947	"	304	309	7130	5110	--	2110	65.97	798	911
35948	"	296	284	7970	4790	--	1980	68.00	827	1010
35949	"	312	311	8340	4890	--	1870	67.38	844	783
35950	"	323	293	8110	5230	--	2100	66.92	850	910
41567	16 Nov 1981	378	373	1140	15,800	56.61	2200	82.73	1220	1110
41568	"	370	371	998	15,600	56.29	2120	81.78	998	1130
41569	"	401	386	1130	16,100	57.33	2330	80.09	1120	1360
41570	"	384	352	1090	15,500	57.16	1980	85.40	1040	911
41571	"	365	363	1110	19,800	55.70	2200	83.19	1200	1100

Urdzhar Vegetation

Sample no.	Sampling date	Specific activity of radionuclides on sampling date, Bq/kg								
		Cs-137	Sr-90	I-131	I-133	I-135	Sr-89	Zr-95	Te-132	Ba-140
12361	25 Jun 1967	36,200	36,200	1,190,000	38,900	--	237,500	12,900	64,500	103,000
12362	“	34,100	35,500	1,270,000	40,000	--	222,000	12,700	65,500	102,000
12363	“	38,700	36,700	989,000	40,700	--	231,000	14,000	63,600	107,000
12364	“	40,200	35,900	1,210,000	35,300	--	243,000	12,600	64,700	116,000
12365	“	35,100	36,600	1,090,000	39,000	--	230,000	13,000	65,000	100,000
15131	10 Apr 1972	66.90	65.93	399	--	--	1540	20.53	7.98	131
15132	“	62.49	61.89	357	--	--	1440	20.82	8.11	113
15133	“	70.07	66.70	429	--	--	1570	19.70	7.79	140
15134	“	68.37	67.41	384	--	--	1380	18.89	7.66	127
15135	“	64.90	65.22	377	--	--	1500	21.09	8.02	143
19431	10 Jul 1973	38,100	37,800	953,000	1960	--	285,000	14,900	23,200	83,500
19432	“	40,100	36,700	921,000	2060	--	277,000	15,600	18,800	107,000
19433	“	39,800	39,200	964,000	1980	--	284,000	13,900	25,600	76,400
19434	“	32,200	38,800	947,000	2110	--	258,000	12,700	22,600	105,000
19435	“	37,700	35,100	952,000	1720	--	280,000	15,000	23,000	84,000
30124	30 Sep 1976	345	339	9540	13,800	54.62	1910	63.04	983	910
30125	“	337	341	9680	13,400	55.19	1670	64.30	972	913
30126	“	341	328	9240	12,700	54.31	1920	60.89	964	877
30127	“	364	345	9520	15,800	54.09	1720	62.47	1270	887
30128	“	338	319	9470	17,200	54.84	1900	63.50	980	900
35220	30 Sep 1977	197	194	2250	4.17	--	1590	29.03	77.1	301
35221	“	195	187	2340	3.99	--	1440	27.99	76.5	308
35222	“	207	192	2310	4.11	--	1670	31.20	78.4	323
35223	“	193	204	2230	4.09	--	1390	28.46	77.3	271
35224	“	188	190	2150	3.87	--	1600	29.30	77.0	300
35961	20 Mar 1978	288	284	7350	5240	--	1860	58.91	750	815
35962	“	318	276	7860	5110	--	1770	56.98	708	922
35963	“	289	309	7090	4980	--	1560	61.20	766	737
35964	“	265	277	7430	5300	--	2020	57.85	727	1040
35965	“	277	265	7210	5090	--	1900	59.00	755	820
41582	16 Nov 1981	349	345	10,300	13,800	45.70	2020	72.90	1090	996
41583	“	322	334	10,000	12,600	45.37	1780	70.79	944	1110
41584	“	367	349	9890	15,700	45.83	1550	74.31	977	867
41585	“	351	323	11,200	14,100	46.10	2340	69.89	1110	945
41586	“	334	367	10,100	12,800	44.82	2000	73.00	1000	1100

Taskesken Vegetation

Sample no.	Sampling date	Specific activity of radionuclides on sampling date, Bq/kg								
		Cs-137	Sr-90	I-131	I-133	I-135	Sr-89	Zr-95	Te-132	Ba-140
12376	25 Jun 1967	32,700	32,300	802,000	46,700	--	209,000	10,800	54,900	88,900
12377	"	30,700	31,300	1,210,000	45,400	--	195,000	11,100	52,400	90,100
12378	"	29,800	32,700	987,000	47,200	--	217,000	9720	57,800	86,500
12379	"	33,900	28,700	1,110,000	46,100	--	201,000	8970	52,200	100,000
12380	"	31,500	32,500	1,000,000	47,000	--	210,000	11,000	55,000	89,000
15146	10 Apr 1972	58.91	58.06	335	--	--	1340	16.72	6.70	111
15147	"	58.22	58.11	361	--	--	1220	12.99	5.99	104
15148	"	58.66	57.96	355	--	--	1750	18.21	6.87	97.5
15149	"	59.31	58.03	327	--	--	1170	16.93	6.92	123
15150	"	56.97	58.00	333	--	--	1300	17.00	6.55	110
19446	10 Jul 1973	34,900	34,600	831,000	2010	--	253,000	12,600	20,700	72,600
19447	"	37,100	36,400	791,000	2410	--	261,000	14,300	20,000	68,300
19448	"	32,700	32,200	854,000	1840	--	244,000	10,800	24,400	81,100
19449	"	33,300	33,100	811,000	1910	--	235,000	11,100	22,300	72,200
19450	"	35,100	36,100	830,000	2220	--	250,000	13,000	21,000	73,000
30139	30 Sep 1976	302	296	8050	11,600	46.04	1660	41.41	825	768
30140	"	300	301	7850	11,300	45.73	1720	40.93	799	622
30141	"	314	274	8150	12,200	46.11	1580	42.30	833	874
30142	"	322	285	8030	10,600	46.02	1810	39.89	758	755
30143	"	298	307	7920	13,400	45.94	1700	41.09	830	770
35235	30 Sep 1977	174	170	1970	4.76	--	1370	23.62	64.45	254
35236	"	181	173	2110	5.06	--	1110	22.80	65.11	222
35237	"	172	176	1930	4.65	--	1430	24.00	63.75	271
35238	"	170	167	1880	5.11	--	1500	23.57	66.80	233
35239	"	168	165	2070	4.81	--	1400	24.01	64.07	250
35976	20 Mar 1978	254	250	6050	3430	--	1630	48.13	628	688
35977	"	300	257	6130	3380	--	1550	48.50	622	700
35978	"	244	236	5850	3400	--	1830	49.31	598	672
35979	"	276	221	5960	3520	--	1700	46.99	631	666
35980	"	238	216	6110	3150	--	1600	48.09	630	690
41597	16 Nov 1981	309	305	8630	11,100	32.87	1750	59.74	916	843
41598	"	301	306	9030	10,100	30.91	1660	60.31	896	800
41599	"	324	313	8240	11,700	33.00	1840	57.40	911	903
41600	"	311	295	8750	9870	32.57	1720	59.59	934	845
41601	"	307	309	8620	10,700	31.86	1800	60.04	920	840

Makanchy Milk

Sample no.	Sampling date	Specific activity of radionuclides on sampling date, Bq/l								
		Cs-137	Sr-90	I-131	I-133	I-135	Sr-89	Zr-95	Te-132	Ba-140
12351	25 Jun 1967	7620	7960	113,000	5070	*	5,070,000	241,000	1,116,000	1,850,000
12352	"	8020	8160	133,000	4540		4,990,000	227,000	1,220,000	2,120,000
12353	"	7790	7580	94,500	3870		4,810,000	231,000	1,030,000	1,750,000
12354	"	7840	8270	109,000	5010		5,280,000	260,000	1,140,000	1,710,000
12355	"	7550	7880	111,000	4350		5,100,000	242,000	989,000	2,900,000
15121	10 Apr 1972	28.70	2.95	72.31	--		27,100	371	146	2310
15122	"	26.89	2.87	71.42	--		25,600	369	177	2270
15123	"	29.60	3.05	72.19	--		28,100	383	123	2240
15124	"	30.00	2.66	74.00	--		24,800	400	169	2510
15125	"	25.92	3.01	71.88	--		27,000	370	151	2300
19421	10 Jul 1973	8140	844	86,300	217		4,910,000	267,000	421,000	1,450,000
19422	"	7840	796	85,100	211		4,660,000	271,000	427,000	1,660,000
19423	"	8060	823	88,600	198		4,910,000	264,000	409,000	1,250,000
19424	"	8450	867	87,400	207		4,950,000	249,000	426,000	1,410,000
19425	"	8110	835	82,300	229		4,900,000	270,000	420,000	1,500,000
30114	30 Sep 1976	126	13.02	1560	2310		33,500	1140	17,500	16,100
30115	"	111	12.91	1160	2250		33,200	1130	16,500	17,200
30116	"	134	13.12	1640	1980		32,900	1210	15,800	15,900
30117	"	157	12.76	1320	2130		33,100	997	19,900	18,700
30118	"	106	13.22	1740	2050		33,500	1100	18,000	16,000
35210	30 Sep 1977	70.27	7.47	381	--		27,900	524	1250	5350
35211	"	68.98	7.35	378	--		26,800	511	1090	5470
35212	"	69.87	7.58	412	--		27,100	491	1220	5280
35213	"	70.09	6.97	398	--		25,600	536	1120	5110
35214	"	70.11	8.01	332	--		28,000	520	1300	5410
35951	20 Mar 1978	105	10.94	851	873		33,100	1070	13,300	14,400
35952	"	111	11.04	865	866		31,100	1020	12,900	14,600
35953	"	103	10.55	831	894		33,600	1270	13,300	15,000
35954	"	97.5	10.68	859	901		32,000	1150	15,000	16,100
35955	"	121	11.14	847	875		33,000	1100	13,600	14,100
41572	16 Nov 1981	12.73	13.11	--	--		--	--	--	--
41573	"	11.99	12.85	--	--		--	--	--	--
41574	"	15.21	13.09	--	--		--	--	--	--
41575	"	12.22	13.14	--	--		--	--	--	--
41576	"	11.78	12.96	--	--		--	--	--	--

** - Values for I-135 below detectable limits because of short (6.6 hr) half life and long time interval between test date and sampling*

Urdzhar Milk

Sample no.	Sampling date	Specific activity of radionuclides on sampling date, Bq/l								
		Cs-137	Sr-90	I-131	I-133	I-135	Sr-89	Zr-95	Te-132	Ba-140
12366	25 Jun 1967	7150	747	103,000	4860	*	3,790,000	207,000	1,030,000	1,640,000
12367	"	7130	733	128,000	3710		3,550,000	224,000	1,080,000	1,690,000
12368	"	7050	768	99,300	3980		3,810,000	206,000	984,000	1,310,000
12369	"	6970	755	97,800	5060		3,730,000	200,000	1,050,000	1,570,000
12370	"	7260	749	101,000	2550		3,800,000	210,000	1,000,000	1,600,000
15136	10 Apr 1972	22.40	2.35	60.52	--		24,700	327	130	2080
15137	"	22.46	2.24	58.40	--		27,100	300	145	2170
15138	"	21.60	2.15	60.37	--		26,200	344	134	1990
15139	"	20.97	2.67	59.79	--		21,900	329	125	2280
15140	"	21.72	2.49	61.08	--		25,000	330	133	2100
19436	10 Jul 1973	7470	784	80,900	203		4,560,000	239,000	384,500	1,330,000
19437	"	7520	791	81,700	201		4,440,000	237,000	379,000	1,230,000
19438	"	7660	689	78,700	198		4,230,000	258,000	411,000	1,510,000
19439	"	7130	722	80,000	200		4,750,000	248,000	369,000	1,270,000
19440	"	8010	797	81,100	233		4,600,000	240,000	380,000	1,300,000
30129	30 Sep 1976	116	12.01	1410	2080		30,600	1000	15,700	14,500
30130	"	99.6	11.91	1350	2110		29,800	1110	14,600	13,500
30131	"	125	12.11	1390	2240		31,100	873	15,700	17,200
30132	"	111	11.65	1230	1980		26,900	1090	16,000	15,400
30133	"	106	11.84	1440	2030		31,000	900	13,900	14,000
35225	30 Sep 1977	66.09	6.87	343	--		25,300	462	1210	4800
35226	"	66.07	6.78	298	--		24,400	479	1270	4910
35227	"	65.98	6.92	352	--		25,100	511	992	4720
35228	"	66.11	7.13	339	--		23,800	422	1160	5000
35229	"	65.27	6.46	341	--		25,000	460	1200	4550
35966	20 Mar 1978	96.71	10.03	768	786		30,200	938	11,900	13,000
35967	"	96.59	10.25	733	726		30,000	927	10,900	14,700
35968	"	97.26	9.96	818	711		28,800	889	11,200	13,300
35969	"	96.29	10.11	773	793		29,100	911	13,300	12,700
35970	"	96.65	9.87	744	806		29,300	940	12,000	13,100
41587	16 Nov 1981	11.73	11.24	--	--		--	--	--	--
41588	"	14.00	11.60	--	--		--	--	--	--
41589	"	9.75	10.78	--	--		--	--	--	--
41590	"	12.03	10.55	--	--		--	--	--	--
41591	"	11.18	11.20	--	--		--	--	--	--

** - Values for I-135 below detectable limits because of short (6.6 hr) half life and long time interval between test date and sampling*

Taskesken Milk

Sample no.	Sampling date	Specific activity of radionuclides on sampling date, Bq/l								
		Cs-137	Sr-90	I-131	I-133	I-135	Sr-89	Zr-95	Te-132	Ba-140
12381	25 Jun 1967	8980	941	123,000	5610	*	3,350,000	173,500	884,000	1,420,000
12382	"	8390	922	114,000	3990		3,330,000	145,000	891,000	1,310,000
12383	"	9240	897	127,000	2370		3,290,000	201,000	1,060,000	1,630,000
12384	"	8880	954	143,000	6060		3,570,000	168,000	872,000	1,380,000
12385	"	8650	943	101,000	4320		3,310,000	170,000	1,080,000	1,400,000
15151	10 Apr 1972	19.81	2.05	51.03	--		21,400	266	109	1750
15152	"	19.73	2.11	52.00	--		20,000	267	117	1640
15153	"	17.77	2.03	51.19	--		23,100	288	98.0	1910
15154	"	20.01	2.01	51.40	--		20,900	256	129	1520
15155	"	18.72	1.89	50.87	--		22,200	271	110	1700
19451	10 Jul 1973	6880	719	71,300	178		4,050,000	201,000	331,000	1,160,000
19452	"	7090	711	69,700	166		4,000,000	208,000	328,000	1,090,000
19453	"	6920	744	68,300	183		3,870,000	222,000	324,000	1,220,000
19454	"	6540	708	71,000	208		3,790,000	196,000	355,000	1,300,000
19455	"	6760	689	70,300	173		3,960,000	200,000	330,000	1,110,000
30144	30 Sep 1976	102	10.52	1180	1750		26,400	816	13,200	12,200
30145	"	97.3	10.90	1090	1680		25,500	849	12,300	12,700
30146	"	104	10.00	1110	1830		23,700	798	13,000	15,100
30147	"	101	10.21	1080	1660		26,800	777	12,900	11,300
30148	"	98.2	11.02	1210	1810		26,100	820	12,700	12,000
35240	30 Sep 1977	58.32	6.03	290	--		21,800	376	1020	4040
35241	"	63.10	5.97	298	--		20,900	333	1080	4090
35242	"	54.96	6.11	271	--		21,100	429	1040	3940
35243	"	60.30	5.81	288	--		19,800	375	947	3610
35244	"	56.62	6.01	293	--		21,600	380	1000	4260
35981	20 Mar 1978	85.33	8.83	911	6640		26,000	763	10,100	11,000
35982	"	85.90	8.77	923	658		24,800	747	10,000	12,500
35983	"	85.11	8.09	904	677		27,100	761	9870	10,700
35984	"	84.89	9.23	897	644		25,500	750	8990	12,200
35985	"	83.99	9.11	902	692		26,000	800	10,800	9970
41602	16 Nov 1981	10.40	10.72	--	--		--	--	--	--
41603	"	10.51	10.59	--	--		--	--	--	--
41604	"	11.00	11.00	--	--		--	--	--	--
41605	"	10.79	10.94	--	--		--	--	--	--
41606	"	10.35	10.63	--	--		--	--	--	--

** - Values for I-135 below detectable limits because of short (6.6 hr) half life and long time interval between test date and sampling*

Table B-1. Specific activity in soil samples, layer 0-5 cm, Bq/kg.

Sampling location	Radionuclides					
	Sr-90	Cs-137	K-40	Ra-226	Th-232	U-235
Makanchy Region						
Bakhty	6.291±1.880	7.132±1.070	526.5±56.44	35.51±10.34	25.41±7.623	3.459±1.238
Karatal	5.392±1.134	6.131±1.794	548.0±49.32	29.47±9.003	26.18±7.825	3.072±1.270
Makanchy	4.051±1.293	5.951±1.947	504.6±45.36	26.63±7.853	21.44±6.343	2.381±1.276
Karabuta	1.411±0.423	2.342±0.693	611.3±55.11	30.21±9.032	23.52±7.054	3.111±1.485
Blagodar-noye	1.011±0.336	1.978±0.584	626.2±56.34	28.74±8.702	27.01±8.104	2.788±1.274
Kirovka	0.956±0.287	1.425±0.438	584.5±52.56	27.52±8.184	22.98±6.914	3.335±1.483
Urdzhar Region						
Urdzhar	3.278±1.001	4.341±1.235	470.6±42.36	26.27±7.814	31.62±9.383	3.952±1.921
Aksakovka	0.821±0.296	1.372±0.432	456.8±41.04	27.01±8.190	30.05±9.189	4.003±1.084
Irinovka	0.798±0.237	0.911±0.264	474.8±42.75	28.32±8.425	33.11±9.575	3.571±1.736
Besterek	2.345±0.721	3.524±1.003	511.6±45.99	25.11±7.529	29.84±9.390	3.245±1.894
Novoan-dreevka	1.366±0.392	2.431±0.721	492.7±44.28	29.01±8.733	32.17±8.864	3.982±2.063
Alekse-yevka	0.364±0.104	0.427±0.129	523.9±47.07	26.34±7.814	31.62±14.92	3.621±1.489
Taskesken Region						
Laibulak	2.936±0.873	4.002±1.163	675.5±60.75	20.96±6.323	34.19±13.09	2.984±1.126
Predgornoe	2.524±0.704	3.860±1.223	734.1±66.06	22.17±6.611	36.02±14.86	2.245±1.674
Tekebulak	2.327±0.637	3.004±1.400	622.4±55.98	21.48±6.001	32.14±14.87	2.611±1.045
Taskesken	2.101±0.582	3.511±1.002	790.2±71.13	21.33±6.032	35.84±12.53	2.582±1.053
Zhanama	0.573±0.166	0.972±0.291	684.3±61.56	19.92±6.041	33.71±15.35	2.097±0.784

Table B-2. Layer by layer distribution of average values for alpha, beta, and gamma radiation in the soil (values in counts/cm).

Population point	Depth (cm)	Alpha radiation	Gamma radiation	Gamma + beta radiation	Beta radiation
Bakhty	0	0.12±0.024	3.68±0.736	6.25±0.911	2.57±1.171
	5	0.44±0.078	4.40±0.792	6.70±1.002	2.30±1.277
	10	0.18±0.036	4.00±0.621	5.88±0.778	1.88±0.995
	20	0.63±0.106	4.13±0.743	6.44±0.932	2.31±1.191
	30	0.20±0.040	4.50±0.876	8.00±1.011	3.50±1.338
	40	0.59±0.111	2.88±0.478	6.00±0.879	3.12±1.001
	50	0.70±0.126	3.00±0.542	6.20±0.912	3.20±1.061
	60	0.21±0.042	4.40±0.785	7.80±1.101	3.40±1.352
	70	0.18±0.038	3.90±0.611	5.87±0.867	1.97±1.061
	80	0.11±0.022	3.85±0.770	6.20±0.894	2.35±1.178
	90	0.15±0.031	3.80±0.754	5.99±0.856	2.19±1.140
Makanchy	0	0.32±0.062	5.00±0.911	8.50±1.117	3.00±1.441
	5	0.27±0.049	4.40±0.779	12.37±1.655	7.97±1.829
	10	0.47±0.091	5.63±0.845	7.68±1.114	2.05±1.398
	20	0.21±0.041	6.38±0.897	13.40±1.977	7.02±2.171
	30	0.12±0.023	5.50±0.822	8.38±1.137	2.88±1.403
	40	0.21±0.039	8.70±1.013	13.57±1.869	4.87±2.125
	50	0.23±0.033	6.42±0.679	7.38±0.907	0.96±1.133
	60	0.21±0.042	4.80±0.714	13.00±1.874	8.20±2.005
	70	0.21±0.039	5.19±0.778	10.22±1.332	5.03±1.543
	80	0.27±0:044	4.80±0.699	6.88±1.032	2.08±1.246
	90	0.16±0.032	4.25±0.765	5.70±0.833	1.45±1.131
Urdzhar	0	0.74±0.131	4.25±0.754	6.80±1.002	2.55±1.254
	5	0.51±0.092	4.75±0.613	5.86±0.769	1.11±0.983
	10	0.60±0.127	4.88±0.732	7.25±1.008	2.37±1.245
	20	0.42±0.096	4.63±0.687	6.00±0.891	1.37±1.125
	30	0.82±0.121	4.62±0.654	5.83±0.784	1.21±1.021
	40	1.77±0.265	5.29±0.794	8.38±1.132	3.09±1.382
	50	0.73±0.131	4.43±0.656	7.14±1.007	2.71±1.201
	60	1.06±0.159	4.53±0.661	7.20±0.996	2.67±1.195
	70	0.47±0.085	3.88±0.582	6.29±0.914	2.41±1.084
	80	0.38±0.021	3.00±0.398	7.40±1.001	4.40±1.077
	90	0.97±0.146	3.60±0.503	7.00±0.967	3.40±1.089
Taskesken	0	0.035±0.019	3.67±0.531	6.86±1.003	3.19±1.134
	5	0.080±0.012	3.67±0.552	6.70±0.944	3.03±1.094
	10	0.030±0.005	2.50±0.375	7.75±1.016	5.25±1.083
	20	0.070±0.010	3.55±0.522	5.88±0.876	2.33±1.019
	30	0.050±0.011	3.61±0.514	6.71±1.006	3.10±1.129
	40	0.062±0.008	3.62±0.541	7.82±1.113	4.20±1.238
	50	0.062±0.012	3.55±0.498	7.67±1.131	4.12±1.236
	60	0.040±0.009	3.86±0.564	5.63±0.745	1.77±0.934
	70	0.032±0.018	3.91±0.585	5.58±0.764	1.67±0.962
	80	0.100±0.015	4.21±0.621	5.63±0.698	1.42±0.934
	90	0.067±0.011	2.58±0.477	3.92±0.498	1.34±0.689

Table B-3. Layer by layer specific activity in soil samples at Bakhty, Bq/kg.

Soil layer	Sr-90	Cs-137	K-40	Ra-226	Th-232	U-235
0-5 cm	6.296±1.888	7.130±1.070	526.5±56.44	35.51±10.65	25.41±7.623	3.459±1.138
5-10	6.867±1.476	5.121±0.768	469.4±47.32	35.43±10.63	23.09±8.072	4.016±1.096
10-20	5.301±1.384	4.436±0.957	445.4±40.09	33.36±10.89	22.55±8.063	3.475±1.125
20-30	6.210±1.111	5.130±0.780	608.8±54.79	29.59±8.893	24.02±7.341	2.677±1.119
30-40	1.528±0.458	1.188±0.335	561.3±57.71	31.57±9.472	26.28±7.883	2.709±1.097
40-50	1.315±0.394	1.117±0.339	591.6±46.28	37.45±9.111	31.58±9.472	3.537±1.744
50-60	2.416±0.723	1.196±0.345	503.0±50.06	30.02±9.014	25.40±7.923	2.141±1.073
60-70	0.762±0.228	0.617±0.476	356.4±37.81	41.21±7.893	22.98±9.744	2.431±1.087
70-80	1.424±0.421	1.014±0.450	339.5±40.21	38.47±8.365	20.25±8.451	4.504±2.157
80-90	1.452±0.443	1.324±0.397	272.8±35.31	35.10±10.53	17.30±8.432	4.325±2.001
90-100	1.371±0.648	1.105±0.332	204.5±28.33	46.15±9.692	15.02±6.423	4.631±1.948

Table B-4. Layer by layer specific activity in soil samples at Makanchy, Bq/kg.

Soil layer	Sr-90	Cs-137	K-40	Ra-226	Th-232	U-235
0-5 cm	4.051±1.103	5.951±1.145	504.0±80.51	26.63±7.99	21.44±10.32	2.381±1.043
5-10	4.603±1.109	4.325±1.784	620.1±60.14	25.04±8.11	22.53±9.74	3.962±0.973
10-20	6.923±1.078	5.551±1.327	650.4±58.22	29.61±6.36	23.17±8.22	2.845±1.054
20-30	7.541±1.007	6.412±1.946	728.3±46.74	31.91±5.23	35.62±6.26	4.001±0.731
30-40	4.117±1.034	3.223±1.059	745.9±44.23	25.62±8.07	21.59±9.89	3.781±0.987
40-50	1.791±0.537	1.453±0.526	495.6±77.54	22.54±9.41	22.73±9.56	2.678±1.063
50-60	2.072±1.001	1.686±0.695	670.2±47.21	22.48±9.74	20.71±10.39	2.645±1.049
60-70	1.955±0.582	1.331±0.399	430.7±79.32	24.81±9.35	21.72±9.22	3.541±1.001
70-80	1.643±0.662	1.356±0.407	600.1±60.15	31.72±5.43	23.31±8.01	2.623±1.018
80-90	1.433±0.678	0.956±0.384	550.5±75.32	25.37±8.04	32.90±7.22	4.801±0.574
90-100	1.202±0.483	1.112±0.411	560.5±70.23	17.28±7.75	21.09±10.44	3.733±0.837

Table B-5. Layer by layer specific activity in soil samples, Urdzhar, Bq/kg.

Layer, см	Sr-90	Cs-137	K-40	Ra-226	Th-232	U-235
0-5	3.278±0.908	4.341±1.131	470.6±42.35	26.23±7.87	31.62±9.83	3.952±1.181
5-10	4.051±1.132	4.002±1.032	630.0±56.74	30.81±9.26	25.63±7.25	6.253±0.665
10-20	6.624±1.732	5.325±1.134	610.8±54.97	28.24±8.45	32.11±5.28	4.851±1.032
20-30	3.711±0.963	3.125±0.866	610.8±60.71	21.33±5.94	35.43±4.34	5.063±0.754
30-40	2.210±0.653	2.265±0.680	881.0±79.29	35.91±9.38	37.21±7.83	6.064±0.654
40-50	1.435±0.432	1.342±0.397	750.3±67.53	25.32±8.39	29.37±5.43	4.401±1.034
50-60	1.992±0.553	1.263±0.438	580.9±52.28	25.64±8.37	27.34±6.83	3.951±1.451
60-70	1.967±0.545	1.392±0.352	560.8±50.47	29.83±7.65	28.16±8.94	3.241±1,523
70-80	1.625±0.450	1.243±0.441	840.4±75.61	35.22±6.69	29.15±7.74	5.054±0.501
80-90	1.341±0.371	0.945±0.283	790.3±71.13	31.42±8.63	29.33±6.73	4.087±1.003
90-100	1.423±0.394	1.023±0.307	650.4±58.54	22.56±6.35	26.14±8.33	5.024±0.532

Table B-6. Layer by layer specific activity in soil samples, Taskesken, Bq/kg.

Layer, cm	Sr-90	Cs-137	K-40	Ra-226	Th-232	U-235
0-5	2.101±0.582	3.551±1.693	790.2±71.10	21.33±5.253	35.84±7.153	2.582±0.653
5-10	4.124±1.035	3.446±1.263	831.0±74.79	29.41±7.258	40.01±6.893	2.815±0.624
10-20	4.366±1.145	2.112±1.022	620.5±55.82	28.56±7.234	37.02±7.003	2.728±0.634
20-30	2.398±0.611	0.914±0.356	741.6±66.73	25.41±6.251	26.62±7.873	2.545±0.703
30-40	1.834±0.592	0.711±0.562	697.8±62.82	26.97±6.757	37.51±6.969	3.309±0.564
40-50	1.792±0.496	1.007±1.521	715.5±64.40	30.01±7.504	31.13±7.300	2.714±0.632
50-60	0.902±0.257	0.951±0.423	829.3±74.64	23.23±5.750	39.48±6.937	3.772±0.509
60-70	0.686±0.178	1.038±0.526	559.9±50.33	30.28±7.500	30.21±7.473	2.472±0.697
70-80	0.755±0.129	0.897±0.261	585.9±52.74	34.62±6.937	28.49±7.676	3.139±0.574
80-90	0.759±0.162	0.752±0.242	805.2±72.41	33.31±7.154	29.67±7.563	2.632±0.645
90-100	0.662±0.195	0.901±0.396	573.5±51.56	26.92±7.035	33.64±7.253	2.893±0.629

Table B-7. Specific activity in vegetation from different locations, Bq/kg.

Sampling location	Sr-90	Cs-137	K-40	Ru-106	Ra-226	Th-232
Makanchy District						
Bakhty	1.347±0.214	1.917±0.575	115.8±17.25	5.907±1.936	3.811±1.034	1.263±0.434
Karatal	1.123±0.227	1.852±0.498	224.4±30.45	4.238±1.601	1.301±0.483	1.673±0.543
Makanchy	0.917±0.254	1.729±0.469	313.9±46.95	5.616±1.862	5.020±1.639	1.368±0.434
Karabuta	0.892±0.197	0.937±0.286	280.1±32.64	5.729±1.894	1.460±0.549	1.254±0.376
Blagodarnoye	0.762±0.201	0.876±0.246	225.8±30.17	3.048±1.005	3.412±1.076	1.780±0.532
Kirovka	0.478±0.132	0.788±0.237	161.9±24.15	5.791±1.451	4.838±1.556	2.301±0.734
Urdzhar District						
Urdzhar	1.951±0.487	1.704±0.548	98.76±14.23	5.191±1.295	5.618±1.921	2.675±0.827
Aksakovka	0.432±0.114	0.773±0.248	187.5±28.05	2.853±0.926	2.675±0.833	2.618±0.803
Irinovka	0.463±0.121	0.524±0.176	137.2±22.61	2.910±0.921	4.548±1.543	3.412±1.001
Besterek	1.057±0.231	0.969±0.313	322.0±47.42	2.502±0.654	3.796±1.132	4.172±1.345
Novoandreevka	0.733±0.206	0.911±0.300	280.4±32.54	2.088±0.445	1.875±0.549	2.887±0.934
Alekseevka	0.224±0.062	0.236±0.072	224.5±30.23	2.956±0.938	2.897±0.859	3.921±1.043
Taskesken District						
Laibulak	0.804±0.223	1.492±0.570	216.5±30.04	4.715±1.554	3.446±1.003	1.011±0.338
Predgornoye	0.772±0.204	1.481±0.543	113.9±17.43	4.973±1.664	2.977±0.937	0.559±0.110
Tekebulak	0.334±0.092	0.601±0.205	220.8±31.25	2.001±0.693	2.918±0.917	0.995±0.239
Taskesken	0.788±0.218	0.820±0.274	293.8±33.15	3.439±1.076	4.088±1.093	0.753±0.240
Zhanaмa	0.243±0.067	0.432±0.124	327.1±49.05	2.733±0.873	2.220±0.734	1.288±0.462

Table B-8. Coefficients of biological absorption and ratio of Cs-137 to Sr-90 in vegetation from different locations

Sampling Location	Cesium-137	Strontium-90	Cesium-137/ Strontium-90
Makanchy District			
Bakhty	0.268	0.214	1.423
Karatal	0.304	0.208	1.649
Makanchi	0.291	0.226	1.885
Karabuta	0,401	0.632	1.051
Blagodarnoe	0.443	0.540	1.150
Kirovka	0.553	0.500	1.649
Urdzhar District			
Urdzhar	0.393	0.595	0.873
Aksakovka	0.563	0.526	1.789
Irinovka	0.575	0.580	1.132
Besterek	0.275	0.451	0.917
Novoandreevka	0.375	0.537	1.243
Alekseevka	0.552	0.615	1.054
Taskesken District			
Laibulak	0.373	0.273	1.856
Predgornoye	0.384	0.306	1.918
Tekebulak	0.194	0.146	1.799
Taskesken	0.234	0.375	1.041
Zhanaмa	0.444	0.424	1.778

Table B-9. Specific activity in milk from different locations, Bq/l.

Sampling Location	Radionuclide					
	Sr-90	Cs-137	K-40	Ru-106	Ra-226	Th-232
Makanchy District						
Bakhty	0.124±0.038	0.147±0.054	49.24±7.386	0.287±0.082	0.324±0.101	0.054±0.012
Karatal	0.098±0.024	0.092±0.003	39.75±5.851	0.253±0.074	0.156±0.021	0.112±0.021
Makanchy	0.111±0.028	0.131±0.038	32.67±5.452	0.319±0.105	0.421±0.134	0.079±0.027
Karabuta	0.074±0.026	0.053±0.017	21.85±3.745	0.334±0.093	0.147±0.035	0.063±0.021
Blagodarnoye	0.062±0.021	0.045±0.015	18.32±2.947	0.104±0.024	0.321±0.101	0.154±0.043
Kirovka	0.037±0.011	0.044±0.014	35.04±5.896	0.321±0.083	0.408±0.126	0.157±0,043
Urdzhar District						
Urdzhar	0.103±0.031	0.126±0.035	32.74±4.879	0.181±0.058	0.423±0.115	0.131±0.033
Aksakovka	0.029±0.009	0.033±0.011	18.35±2.974	0.073±0.002	0.254±0.078	0.098±0.023
Irinovka	0.033±0.010	0.029±0.009	17.99±2.546	0.098±0.035	0.352±0.093	0.176±0.054
Besterek	0.094±0.031	0.064±0.019	30.02±4.347	0.044±0.011	0.311±0.063	0.196±0.065
Novoandre-yevka	0.066±0.020	0.058±0.014	28.41±4.049	0.052±0.013	0.152±0.049	0.157±0.043
Alekseevka	0.014±0.004	0.015±0.004	22.15±3.224	0.101±0.036	0.268±0.076	0.183±0.058
Taskesken District						
Laibulak	0.086±0.023	0.114±0.034	45.82±6.498	0.143±0.038	0.173±0.045	0.162±0.053
Predgornoye	0.083±0.022	0.082±0.021	32.86±4.586	0.078±0.021	0.120±0.033	0.039±0.012
Tekebulak	0.041±0.012	0.063±0.018	48.61±6.805	0.041±0.012	0.071±0.023	0.044±0.015
Taskesken	0.082±0.022	0.075±0.019	23.57±3.264	0.057±0.013	0.084±0.028	0.078±0.021
Zhanaмa	0.029±0.009	0.033±0.009	32.21±4.084	0.039±0.011	0.034±0.012	0.095±0.028

Table B-10. Specific activity in meat from different locations, Bq/kg.

Sampling location	Radionuclide					
	Sr-90	Cs-137	K-40	Ru-106	Ra-226	Th-232
Makanchy District						
Bakhty	0.096±0.028	0.165±0.021	27.16±4.050	0.483±0.194	0.464±0.178	0.146±0.044
Karatal	0.075±0.019	0.150±0.022	22.29±3.187	0.249±0.086	0.310±0.121	0.172±0.057
Makanchy	0.101±0.029	0.124±0.017	33.97±4.576	0.307±0.102	1.523±0.544	0.124±0.033
Karabuta	0.061±0.016	0.060±0.012	28.37±4.135	0.346±0.121	0.284±0.095	0.111±0.035
Blagodar-noye	0.063±0.017	0.057±0.012	22.74±3.175	0.172±0.064	0.321±0,128	0.227±0.067
Kirovka	0.034±0.009	0.048±0.014	20.94±2.964	0.473±0.154	0.788±0.241	0.257±0.078
Urdzhar District						
Urdzhar	0.094±0.024	0.114±0.026	10.81±1.398	0.296±0.095	0.360±0.118	0.260±0.082
Aksakovka	0.030±0.008	0.049±0.014	14.41±2.084	0.046±0.013	0.179±0.057	0.259v0.082
Irinovka	0.034±0.008	0.042±0.013	15.02±2.187	0.026±0.008	0.131±0.045	0.271±0.087
Besterek	0.069±0.019	0.087±0.022	20.93±2.869	0.019±0.006	0.326±0.106	0.392±0.124
Novoandre-yevka	0.050±0.017	0.063±0.012	20.52±2.765	0.052±0.012	0.183±0.064	0.264±0.084
Alekseevka	0.019±0.005	0.015±0.005	19.27±2.587	0.053±0.013	0.268±0.092	0.287±0.086
Taskesken District						
Laibulak	0.078±0.021	0.098±0.031	27.72±3.941	0.226±0.075	0.311±0.109	0.089±0.022
Predgornoye	0.069±0.018	0.084±0.028	19.78±2.659	0.163±0.056	0.279±0.056	0.024±0.008
Tekebulak	0.033±0.008	0.077±0.023	28.34±4.073	0.101±0.035	0.284±0.091	0.073±0.023
Taskesken	0.075±0.021	0.082±0.029	31.55±4.467	0.144±0.034	0.328±0.098	0.055±0.019
Zhanaмa	0.022±0.006	0.041±0.012	32.18±4.793	0.172±0.039	0.233±0.076	0.096±0.031

Table B-11. Transfer coefficients of Sr-90 and Cs-137.

Sampling Location	Vegetation to Milk		Vegetation to Meat	
	Sr-90	Cs-137	Sr-90	Cs-137
Makanchy District				
Bakhty	0.092	0.077	0.072	0.086
Karatal	0.087	0.050	0.067	0.081
Makanchy	0.121	0.076	0.110	0.072
Karabuta	0.083	0.057	0.068	0.064
Blagodarnoe	0.081	0.051	0.063	0.065
Kirovka	0.077	0.056	0.071	0.061
Urdzhar District				
Urdzhar	0.053	0.074	0.048	0.067
Aksakovka	0.068	0.043	0.069	0.063
Irinovka	0.071	0.042	0.073	0.060
Besterek	0.089	0.066	0.065	0.090
Novoandreevka	0.090	0.064	0.068	0.069
Alekseevka	0.064	0.064	0.083	0.030
Taskesken District				
Laibulak	0.107	0.076	0.097	0.065
Predgornoe	0.108	0.055	0.089	0.056
Tekebulak	0.123	0.105	0.099	0.128
Taskesken	0.104	0.091	0.095	0.100
Zhanama	0.121	0.076	0.089	0.095

Table B-12. Specific activity in animal bones from different locations, Bq/kg.

Sampling Location	Radionuclides					
	Sr-90	Cs-137	K-40	Ru-106	Ra-226	Th-232
Makanchy District						
Bakhty	6.823±2.098	2.141±0.732	35.81±7.005	11.62±3.650	4.914±1.594	3.918±1.284
Karatal	6.312±2.031	1.671±0.387	43.89±6.104	7.136±2.347	1.269±0.434	4.345±1.443
Makanchi	8.429±2.834	1.223±0.287	49.91±7.034	9.532±3.026	8.679±2.674	4.131±1.245
Karabuta	5.467±1.785	0.657±0.128	46.63±6.552	10.02±3.388	1.313±0.349	3.613±1.043
Blagodarnoye	3.786±1.021	0.427±0.146	43.51±6.105	6.143±2.053	3.428±1.036	5.028±1.634
Kirovka	3.067±1.006	0.412±0.113	37.86±5.291	10.22±3.357	6.841±2.249	5.321±1.743
Urdzharsky District						
Urdzhar	7.626±2.367	1.201±0.352	27.98±3.976	9.345±3.105	9.412±3.040	6.445±2.102
Aksakovka	3.224±1.078	0.339±0.117	38.42±5.356	4.919±1.362	2.494±0.618	5.832±1.983
Irinovka	2.987±0.914	0.226±0.103	37.64±5.241	5.027±1.624	6.525±2.047	9.381±3.104
Besterek	5.013±1.745	0.664±0.216	52.64±7.467	3.376±1.103	4.538±1.342	11.27±3.638
Novoan-dreevka	4.117±1.562	0.619±0.196	48.96±6.984	4.031±1.343	1.825±0.683	6.544±2.197
Alekseyevka	1.891±0.624	0.198±0.084	42.77±6.053	5.273±1.743	2.543±0.628	10.83±3.539
Taskesken District						
Laibulak	7.611±2.372	0.879±0.243	40.16±5.749	7.333±2.378	3.406±1.036	3.542±1.132
Predgornoye	7.490±2.680	0.861±0.218	34.24±4.892	7.417±2.343	2.911±0.933	2.424±0.803
Tekebulak	5.364±1.459	0.585±0.163	42.11±6.034	3.922±1.234	2.861±0.804	2.983±0.834
Taskesken	6.514±2.021	0.619±0.212	44.56±6.342	6.839±2.282	6.008±1.794	2.861±0.823
Zhanama	2.002±0.673	0.179±0.058	54.01±7.587	4.001±1.294	2.005±0.634	4.087±1.365

APPENDIX C

Data on Population Description and on Standard Mortality Ratios

Table C-1. Dynamics of number of radiation risk groups among the population of Makanchy District (thousands).

	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
M	9.5	9.5	10.0	10.0	10.0	10.3	11.0	11.2	12.0	12.2	12.3
F	10.5	11.0	11.0	11.5	11.0	12.0	12.4	13.0	13.0	13.3	14.0
Total	20.0	20.5	21.0	21.5	21.0	22.3	23.4	24.2	25.0	25.2	26.3
	1960	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**
M	13.0	13.0	14.0	14.2	14.0	14.2	14.2	14.5	14.6	14.8	14.5
F	14.0	14.5	14.0	15.6	15.0	15.0	15.3	15.3	15.0	15.2	15.0
Total	27.0	27.5	28.0	29.8	29.0	29.2	29.5	29.8	29.6	30.0	29.5
	1971	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**
M	14.8	14.8	15.0	15.2	15.4	15.5	15.8	15.8	15.8	15.8	16.0
F	15.7	16.0	16.0	16.0	16.2	16.3	16.5	17.2	18.0	18.2	18.2
Total	30.5	30.8	31.0	31.2	31.6	31.8	32.3	33.0	33.8	34.0	34.2
	1982	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
M	16.4	16.7	16.8	17.0	17.2	17.2	17.5	16.6	16.7	17.0	17.5
F	19.0	19.0	19.0	19.0	19.0	19.2	19.0	19.3	20.2	20.1	20.0
Total	35.4	35.7	35.8	36.0	36.2	36.4	36.5	36.9	36.9	37.1	37.5
	1993	**1994**	**1995**	**1996**							
M	17.8	18.0	18.3	18.5							
F	20.5	21.1	21.0	21.0							
Total	38.3	39.1	39.3	39.5							

Table C-2. Dynamics of number of radiation risk groups among the populations of Urdzhar and Taskesken Districts (thousands).

	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
M	17.0	18.0	18.0	18.5	19.0	19.0	19.5	20.0	21.0	21.5	22.0
F	20.5	20.3	20.5	20.5	20.5	20.8	21.1	22.4	22.8	23.7	24.2
Total	37.5	38.3	38.5	39.0	39.5	39.8	40.6	42.4	43.8	45.2	46.2
	1960	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**
M	23.0	23.2	24.2	25.8	25.0	26.5	26.0	26.6	27.0	27.4	28.0
F	24.3	25.0	26.0	27.0	26.9	26.1	27.8	28.0	28.2	29.0	29.2
Total	47.3	48.2	5 0.2	52.8	51.9	52.6	53.8	54.6	55.2	56.4	57.2
	1971	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**
M	28.3	28.0	28.3	29.0	29.8	30.0	30.4	30.2	31.3	32.0	33.0
F	29.5	29.8	30.0	30.4	31.4	32.0	32.4	34.0	34.0	34.4	34.0
Total	57.8	57.8	58.3	59.4	61.2	62.0	62.8	64.2	65.3	66.4	67.0
	1982	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
M	33.8	34.5	35.0	36.5	36.5	37.2	38.5	39.4	40.5	41.0	41.5
F	34.7	36.0	36.8	37.0	39.4	40.0	42.0	43.0	43.0	43.5	43.5
Total	68.5	70.5	71.8	73.5	75.9	77.2	80.5	82.4	83.5	84.5	85.0
	1993	**1994**	**1995**	**1996**							
M	41.7	42.0	43.3	42.0							
F	43.5	43.5	43.0	45.0							
Total	85.2	85.5	86.3	87.0							

Table C-3. Dynamics of number of radiation risk groups among the population of Kokpekty Control District (thousands).

	1949	**1950**	**1951**	**1952**	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1959**
M	10.0	10.0	10.5	10.8	11.0	11.0	11.8	12.0	12.0	12.0	12.5
F	10.0	11.2	12.0	12.0	12.5	13.5	13.0	13.2	13.8	14.2	14.5
Total	20.0	21.2	22.5	22.8	23.5	24.5	24.8	25.2	25.8	26.2	27.0
	1960	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**
M	13.0	13.5	13.2	13.5	13.8	13.1	13.3	13.5	13.7	14.0	14.0
F	14.5	14.5	15.0	15.0	15.2	16.0	16.0	16.0	16.0	15.0	15.5
Total	27.5	28.0	28.2	28.5	29.0	29.1	29.3	29.5	29.7	29.0	29.5
	1971	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**
M	14.1	14.0	14.5	14.5	14.2	14.4	14.8	14.4	15.0	15.0	15.5
F	15.5	16.0	16.0	16.5	17.0	17.0	17.0	17.4	17.2	17.8	17.9
Total	29.6	30.0	30.5	31.0	31.2	31.4	31.8	31.8	32.2	32.8	33.4
	1982	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
M	15.2	15.6	15.8	15.5	15.3	15.0	15.2	16.0	16.0	16.0	15.2
F	18.0	18.0	17.0	16.0	17.0	17.0	17.0	16.1	16.4	16.8	16.0
Total	33.2	33.6	32.8	31.5	32.3	32.0	32.2	32.1	32.4	32.8	31.2
	1993	**1994**	**1995**	**1996**							
M	14.5	14.8	14.5	15.0							
F	16.1	16.0	16.5	17.0							
Total	30.6	30.8	31.0	32.0							

Table C-4. Dynamics of standardized indices of the overall level of cancer mortality for the population of Makanchy District (per 100,000).

1949	75	**1959**	72.2	**1969**	90	**1979**	109.5	**1989**	195.1
1950	82.9	**1960**	66.6	**1970**	101.7	**1980**	117.6	**1990**	200.5
1951	90.5	**1961**	80	**1971**	104.9	**1981**	122.8	**1991**	167.1
1952	93.0	**1962**	71.4	**1972**	110.4	**1982**	118.6	**1992**	170.7
1953	85.7	**1963**	83.9	**1973**	112.9	**1983**	126.1	**1993**	156.7
1954	71.7	**1964**	89.7	**1974**	118.6	**1984**	122.9	**1994**	158.6
1955	59.8	**1965**	99.3	**1975**	126.6	**1985**	155.6	**1995**	162.8
1956	70.2	**1966**	91.5	**1976**	128.9	**1986**	163	**1996**	159.5
1957	84	**1967**	83.9	**1977**	111.5	**1987**	214.3		
1958	104	**1968**	94.6	**1978**	118.2	**1988**	208.2		

Table C-5. Dynamics of standardized indices of the overall level of cancer mortality for the population of Urdzhar and Taskesken Districts (per 100,000).

1949	53.3	**1959**	75.7	**1969**	76.2	**1979**	84.2	**1989**	121.3
1950	62.6	**1960**	63.4	**1970**	78.6	**1980**	93.3	**1990**	129.3
1951	67.5	**1961**	64.3	**1971**	83.0	**1981**	94.0	**1991**	125.4
1952	69.2	**1962**	59.7	**1972**	86.5	**1982**	91.9	**1992**	102.3
1953	63.2	**1963**	68.1	**1973**	80.6	**1983**	95.0	**1993**	97.4
1954	60.3	**1964**	73.2	**1974**	85.8	**1984**	96.1	**1994**	101.7
1955	54.1	**1965**	79.8	**1975**	83.3	**1985**	102.0	**1995**	101.9
1956	54.2	**1966**	74.3	**1976**	83.8	**1986**	109.3	**1996**	104.5
1957	66.2	**1967**	73.2	**1977**	79.6	**1987**	110.1		
1958	70.7	**1968**	76.0	**1978**	87.2	**1988**	118.0		

Table C-6. Dynamics of standardized indexes of the overall cancer mortality level for the population of Kokpekty District (per 100,000).

1949	70.0	**1959**	74.0	**1969**	96.5	**1979**	111.8	**1989**	121.4
1950	70.7	**1960**	69.0	**1970**	98.3	**1980**	115.8	**1990**	123.4
1951	80.0	**1961**	75.0	**1971**	101.3	**1981**	116.7	**1991**	115.8
1952	78.9	**1962**	74.4	**1972**	106.6	**1982**	114.4	**1992**	125.0
1953	80.8	**1963**	84.2	**1973**	108.1	**1983**	116.0	**1993**	120.9
1954	69.3	**1964**	86.2	**1974**	112.9	**1984**	121.9	**1994**	120.1
1955	60.4	**1965**	96.2	**1975**	121.7	**1985**	120.6	**1995**	112.9
1956	67.4	**1966**	95.5	**1976**	124.2	**1986**	117.6	**1996**	118.7
1957	73.6	**1967**	91.5	**1977**	116.3	**1987**	121.8		
1958	91.6	**1968**	94.2	**1978**	119.4	**1988**	118.0		

Table C-7. Dynamics of relative risk of overall cancer mortality among the population of the study districts, 1949-1970.

		1949	**1950**	**1951**	**1952**	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1959**
SMR	Maкanchy	0.000750	0.000829	0.000904	0.000930	0.000857	0.000717	0.000598	0.000702	0.000840	0.00101	0.000722
	Urdzhar, Taskesken	0.000533	0.000626	0.000675	0.000692	0.000632	0.000603	0.000541	0.000542	0.000662	0.000707	0.000634
	Kokpekty	0.0007	0.000707	0.0008	0.000789	0.000808	0.000693	0.000604	0.000674	0.000736	0.000916	0.000740
RR	Maкanchy	1.07	1.17	1.13	1.17	1.06	1.03	0.99	1.04	1.14	1.10	0.97
	Urdzhar, Taskesken	0.97	0.88	0.84	0.87	0.78	0.87	0.89	0.80	0.89	0.77	0.85

		1960	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**
SMR	Maкanchy	0.000666	0.000800	0.000714	0.000838	0.000896	0.000993	0.000915	0.000838	0.000945	0.000900	0.00101
	Urdzhar, Taskesken	0.000634	0.000643	0.000597	0.000681	0.000732	0.000798	0.000743	0.000732	0.000760	0.000762	0.000786
	Kokpekty	0.000690	0.000755	0.000744	0.000842	0.000862	0.000962	0.000955	0.000915	0.000942	0.000965	0.000983
RR	Maкanchy	0.96	1.05	0.95	0.99	1.03	1.03	0.95	0.91	1.00	0.93	1.02
	Urdzhar, Taskesken	0.91	0.85	0.80	0.80	0.84	0.82	0.77	0.8	0.80	0.78	0.79

Note: SMR = standardized mortality ratio
RR = relative risk

Table C-8. Dynamics of relative risk of overall cancer mortality among the population of the study districts, 1971-1996.

		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
SMR	Maкanchy	0.00104	0.00110	0.00112	0.00118	0.00126	0.00128	0.00111	0.00118	00.00109	0.00117	0.00122
	Urdzhar, Taskesken	0.000830	0.000865	0.000806	0.000858	0.000833	0.000838	0.000796	0.000872	0.000842	0.000933	0.000940
	Kokpekty	0.00101	0.00106	0.00108	0.0112	0.00121	0.00124	0.00116	0.00119	0.00111	0.00115	0.00116
RR	Maкanchy	1.02	1.03	1.03	1.05	1.04	1.03	0.95	0.99	0.98	1.01	1.05
	Urdzhar, Taskesken	0.82	0.81	0.74	0.76	0.68	0.67	0.68	0.73	0.76	0.81	0.81

		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
SMR	Maкanchy	0.00118	0.00126	0.00122	0.00155	0.00162	0.00214	0.00208	0.00195	0.00200	0.00167	0.00170
	Urdzhar, Taskesken	0.000919	0.000950	0.000961	0.00102	0.00109	0.00110	0.00118	0.00121	0.00129	0.00125	0.00102
	Kokpekty	0.00114	0.00116	0.00121	0.00120	0.00117	0.00121	0.00118	0.00121	0.00123	0.00115	0.00125
RR	Maкanchy	1.03	1.08	1.00	1.29	1.38	1.76	1.76	1.61	1.62	1.45	1.36
	Urdzhar, Taskesken	0.80	0.81	0.79	0.85	0.93	0.90	1.00	1.00	1.04	1.08	0.81

		1993	1994	1995	1996
SMR	Maкanchy	0.00156	0.00158	0.00162	0.00159
	Urdzhar, Taskesken	0.000974	0.00101	0.00101	0.00104
	Kokpekty	0.00120	0.00120	0.00112	0.00118
RR	Maкanchy	1.3	1.31	1.44	1.34
	Urdzhar, Taskesken	0.81	0.84	0.90	0.88

Note: SMR = standardized mortality ratio
RR = relative risk

Table C-9. Dynamics of SMR of the population of Makanchy District by primary sites (per 100,000 population).

	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Esophagus	25.0	29.3	23.8	32.6	23.8	22.4	21.4	16.5	24.0	31.4	19.0	18.5	21.8	17.9	23.5
Stomach	20.0	19.5	19.0	18.6	23.8	17.9	8.5	16.5	20.0	15.7	19.0	14.8	18.2	10.7	16.8
Liver	5.0	4.9	9.5	9.3	9.5	9.0	8.5	8.3	4.0	3.9	3.8	7.4	7.3	3.6	6.7
Intestines	5.0	9.8	9.5	9.3	4.8	4.5	4.3	4.1	4.0	11.8	7.6	-	3.6	10.7	6.7
Pancreas	-	-	4.8	4.7	9.5	9.0	4.3	4.1	4.0	3.9	3.8	3.7	3.6	3.6	3.4
Lung	-	-	4.8	-	-	-	4.3	4.1	4.0	7.8	3.8	3.7	3.6	7.1	6.7
Urinary bladder	5.0	4.9	4.8	4.7	4.8	-	4.3	-	4.0	7.8	-	7.4	7.3	3.6	3.4
Kidney	5.0	4.9	-	4.7	4.8	9.0	-	8.3	8.0	7.8	3.8	3.7	7.3	3.6	3.4
Skin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Breast	-	-	4.8	-	-	4.5	4.3	4.1	4.0	3.9	3.8	3.7	3.6	3.6	3.4
Ovary	5.0	4.9	4.8	4.7	-	-	-	4.1	4.0	3.9	7.6	3.7	3.6	3.6	6.7
Corpus uteri	5.0	-	-	-	4.8	-	-	-	-	3.9	-	-	-	3.6	-
Cervix uteri	-	-	4.8	-	-	-	-	-	-	-	-	-	-	-	-
Gall bladder	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bronchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Melanoma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leukemia ALL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CLL	-	4.9	-	4.7	-	-	-	-	-	-	-	-	-	-	3.4
AML	-	-	-	-	-	-	-	-	4.0	-	-	-	-	-	-
CML	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table C-9. Continued.

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Esophagus	20.7	27.4	27.1	20.1	30.4	20.0	27.1	26.2	35.7	32.2	28.9	28.5	28.3	21.7	24.2	26.6	23.5	23.4	19.8
Stomach	20.7	20.5	23.7	16.8	16.9	20.0	23.7	23.0	29.2	25.8	32.1	34.8	34.6	21.7	24.2	20.7	23.5	23.4	22.6
Liver	6.9	6.8	6.8	6.7	6.8	6.7	6.8	6.6	6.5	9.7	6.4	9.5	6.3	6.2	6.1	5.9	8.8	8.8	5.6
Intestines	10.3	6.8	-	6.7	6.8	6.7	6.8	9.8	6.5	9.7	9.6	12.7	9.4	6.2	12.1	8.9	11.8	11.7	11.3
Pancreas	6.9	3.4	-	6.7	3.4	3.3	3.4	6.6	-	6.5	9.6	6.3	6.3	6.2	9.1	5.9	5.9	8.8	8.5
Lung	6.9	6.8	10.2	6.7	6.8	10.0	3.4	9.8	9.7	9.7	6.4	9.5	12.6	12.4	12.1	11.8	11.8	14.6	14.1
Urinary bladder	3.4	3.4	6.8	3.4	3.4	3.3	6.8	3.3	3.2	-	3.2	6.3	6.3	9.3	6.1	3.0	5.9	5.8	8.5
Kidney	-	3.4	6.8	6.7	6.8	3.3	10.2	6.6	3.2	3.2	6.4	6.3	6.3	6.2	6.1	5.9	8.8	8.8	8.5
Skin	-	3.4	-	-	-	-	-	-	-	-	-	-	3.1	-	3.0	3.0	-	-	-
Breast	3.4	6.8	3.4	3.4	3.4	6.7	6.8	3.3	6.5	6.5	6.4	6.3	6.3	6.2	6.1	8.9	8.8	5.8	8.5
Ovary	3.4	3.4	6.8	6.7	3.4	3.3	3.4	3.3	6.5	3.2	3.2	6.3	6.3	6.2	6.1	5.9	5.9	5.8	5.6
Corpus uteri	3.4	-	-	-	3.4	3.3	-	3.3	-	3.2	-	-	-	3.1	-	3.0	-	2.9	2.8
Cervix uteri	3.4	-	-	-	3.4	-	3.4	3.3	3.2	-	3.2	-	3.1	3.1	3.0	-	2.9	2.9	2.8

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Esophagus	22.4	19.6	22.2	22.1	27.5	24.7	21.7	24.4	18.9	13.3	15.7	15.3	15.3	15.2
Stomach	22.4	22.3	19.4	22.1	30.2	30.1	21.7	27.1	13.5	18.7	13.1	15.3	20.4	15.2
Liver	5.6	5.6	11.1	8.3	11.0	8.2	8.1	5.4	8.1	8.0	5.2	5.1	5.1	5.1
Intestines	11.2	14.0	11.1	13.8	13.7	11.0	10.8	10.8	10.8	10.7	13.1	10.2	10.2	15.2
Pancreas	5.6	8.4	5.6	5.5	8.2	11.0	10.8	10.8	8.1	5.3	5.2	7.7	5.1	5.1
Lung	19.6	16.8	22.2	30.4	35.7	35.6	35.2	32.5	43.1	42.7	39.2	35.8	38.2	35.4
Urinary bladder	8.4	8.4	11.1	8.3	11.0	11.0	8.1	10.8	5.4	8.0	7.8	7.7	5.1	7.6
Kidney	8.4	5.6	5.6	8.3	13.7	11.0	13.6	13.6	2.7	8.0	5.2	10.2	7.6	7.6
Skin	-	-	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.5	2.5
Breast	8.4	8.4	13.9	16.6	19.2	19.2	19.0	21.7	27.0	24.0	23.5	20.5	22.9	20.1
Ovary	5.6	5.6	5.6	5.5	8.2	8.2	8.1	5.4	2.7	2.7	2.6	5.1	5.1	5.1
Corpus uteri	2.8	2.8	2.8	-	2.7	-	2.7	-	-	-	-	-	-	2.5
Cervix uteri	-	2.8	2.8-	-	-	2.7	-	2.7	-	-	-	2.6	-	2.5
Gall bladder	-	-	5.6	5.5	5.5	5.5	5.4	5.4	2.7	2.7	2.6	2.6	5.1	5.1
Brochi	-	-	8.3	5.5	8.2	5.5	5.4	8.1	5.4	8.1	7.8	5.1	7.6	5.1
Melanoma	-	-	2.8	-	2.7	5.5	5.4	2.7	-	5.3	2.6	5.1	5.1	5.1

Table C-10. Dynamics of SMR of the population of Urdzhar and Taskesken Districts by primary sites (per 100,000 population).

	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Esophagus	13.3	18.2	15.5	17.9	17.7	12.5	12.3	14.1	13.6	17.6	15.1	14.7	16.6	15.9	18.9
Stomach	16.0	10.4	15.5	17.9	12.6	12.5	12.3	11.7	13.6	15.4	19.4	12.6	14.5	11.9	15.1
Liver	5.3	5.2	5.1	2.5	2.5	5.0	2.4	4.7	4.5	4.4	6.5	2.1	4.1	3.9	5.6
Intestines	2.6	5.2	7.8	10.2	7.5	5.0	7.3	2.3	6.8	6.6	6.5	4.2	4.1	3.9	3.7
Pancreas	2.6	2.6	2.5	5.1	5.0	5.0	4.9	7.0	4.5	4.4	2.1	2.1	2.0	1.9	3.7
Lung	-	2.6	2.5	-	2.5	2.5	2.4	2.3	2.2	4.4	4.3	4.2	2.0	1.9	3.7
Urinary bladder	2.6	2.6	2.5	2.5	2.5	2.5	-	-	2.2	2.2	2.1	2.1	4.1	3.9	3.7
Kidney	2.6	5.2	2.5	5.1	5.0	5.0	4.9	4.7	4.5	4.4	4.3	4.2	4.1	3.9	3.7
Skin	-	2.6	5.1	-	2.5	2.5	-	-	-	2.2	2.1	-	2.0	1.9	1.8
Breast	-	2.6	-	2.5	2.5	2.5	2.4	2.3	2.2	2.2	4.3	4.2	2.0	1.9	1.8
Ovary	2.6	2.6	2.5	2.6	2.5	2.5	2.4	2.3	2.2	2.2	2.1	4.2	2.0	1.9	1.8
Corpus uteri	2.6	2.6	-	2.5	-	-	2.4	-	2.2	-	2.1	2.1	-	-	-
Cervix uteri	2.6	-	2.5	-	-	2.5	-	2.3	2.2	2.2	-	2.1	2.0	1.9	1.8

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Esophagus	15.4	19.0	16.7	16.4	16.3	19.5	17.4	22.4	22.4	18.8	21.8	17.9	19.3	19.1	18.6	16.8	16.5	17.9	16.0
Stomach	15.4	17.1	16.7	16.4	18.1	15.9	19.2	20.7	20.7	18.8	20.2	17.9	19.3	19.1	17.1	16.8	16.5	14.9	14.5
Liver	7.7	7.6	5.5	7.3	7.2	7.1	6.9	5.1	6.9	5.1	5.0	4.9	4.8	4.7	6.2	6.1	4.5	4.4	4.3
Intestines	3.8	5.7	5.5	3.6	5.4	5.3	5.2	6.9	8.6	8.5	8.4	9.8	9.6	7.9	9.3	9.1	7.5	8.9	5.8
Pancreas	3.8	3.8	3.7	3.6	3.6	3.5	3.4	3.4	3.4	3.4	3.3	3.2	4.8	3.1	3.1	4.5	1.5	2.9	1.4
Lung	5.7	5.7	5.5	5.4	5.4	5.3	5.2	5.1	5.1	5.1	5.0	4.9	6.4	4.7	6.2	4.5	7.5	7.4	7.2
Urinary bladder	3.8	3.8	3.7	3.6	3.6	3.5	5.2	3.4	3.4	3.4	3.3	3.2	3.2	3.1	3.1	4.5	3.0	4.4	4.3
Kidney	3.8	3.8	3.7	3.6	3.6	3.5	3.4	3.4	3.4	3.4	3.3	3.2	3.2	3.1	4.6	3.0	4.5	4.4	5.8
Skin	1.9	1.9	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.6	-	1.5	1.5	3.0	4.4	4.3
Breast	3.8	3.8	3.7	3.6	3.6	3.5	3.4	3.4	3.4	3.4	3.4	3.2	3.2	3.1	3.1	3.0	4.5	4.4	2.9
Ovary	3.8	3.8	3.7	3.6	3.6	3.5	3.4	3.4	3.4	3.4	3.3	3.2	3.2	3.2	3.1	3.0	4.5	4.4	4.3
Corpus uteri	1.9	1.9	1.8	1.8	1.8	1.7	1.7	-	-	1.7	1.6	1.6	-	-	1.5	1.5	3.0	1.4	2.9
Cervix uteri	1.9	1.9	1.8	-	1.8	1.7	1.7	1.7	1.7	-	-	-	1.6	1.5	1.5	1.5	1.5	1.4	1.4
Gall bladder										-	1.6	3.2	1.6	1.5	3.1	3.0	3.0	1.4	2.9
Bronchi										-	-	1.6	-	-	3.1	3.0	1.5	1.4	2.8
Melanoma										1.7	1.6	1.6	1.6	3.1	1.5	1.5	6.02	4.4	5.8

Table C-10. Continued.

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Esophagus	15.6	13.9	16.3	17.1	14.2	13.6	16.9	15.5	15.3	14.1	14.0	14.0	15.0	13.7
Stomach	12.7	15.3	13.6	15.8	15.5	14.9	15.7	16.7	14.2	15.2	14.0	14.0	13.9	14.9
Liver	4.2	4.1	4.0	5.2	5.1	4.9	4.8	4.4	3.5	4.7	4.6	4.6	3.4	4.5
Intestines	7.0	6.9	6.8	6.5	6.4	7.4	6.0	9.5	8.2	5.8	5.8	5.8	5.7	5.7
Pancreas	2.8	2.7	2.7	2.6	2.5	4.9	6.0	8.3	9.4	2.3	2.2	2.3	2.3	4.5
Lung	11.3	11.1	10.8	13.1	15.5	22.3	21.8	23.9	23.6	11.7	11.7	12.8	12.7	13.7
Urinary bladder	4.2	4.1	5.4	6.5	6.5	4.9	4.8	5.9	5.9	5.8	5.8	5.8	5.7	5.7
Kidney	5.6	5.5	6.8	6.5	6.5	6.2	6.0	7.1	7.1	5.8	5.8	5.8	5.7	5.7
Skin	4.2	4.1	4.0	2.6	2.5	2.4	3.6	2.2	1.1	2.3	2.2	3.5	2.3	2.2
Breast	5.6	5.5	5.4	7.9	10.3	12.4	12.1	13.1	13.0	9.4	7.0	9.3	9.2	8.0
Ovary	-	4.1	5.4	5.2	5.1	4.9	4.8	5.9	5.9	4.7	4.6	4.6	4.6	4.5
Corpus uteri	2.8	2.7	2.7	1.3	2.5	-	-	-	-	1.1	1.1	1.1	2.3	2.2
Cervix uteri	4.2	1.3	2.7	1.3	1.3	1.2	1.2	1.1	1.1	2.3	1.1	2.3	1.1	2.2
Gall bladder	1.4	2.7	1.3	1.3	1.3	3.7	3.6	3.6	4.7	1.1	1.1	1.1	2.3	1.1
Bronchi	1.4	2.7	2.7	5.2	5.1	3.7	3.6	2.2	2.3	4.7	4.6	4.6	4.6	4.5
Melanoma	5.6	4.1	6.8	5.2	5.1	3.7	4.8	2.2	3.5	4.7	4.6	3.5	4.6	4.5

Table C-11. Dynamics of SMR of the population of Kokpekty District by primary site (per 100,000 population).

	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Esophagus	20.0	23.5	17.7	21.9	25.5	24.4	24.1	15.8	15.5	22.9	22.2	21.8	17.8	17.7	21.0
Stomach	20.0	14.1	17.7	8.7	21.2	16.3	8.0	15.8	19.3	15.2	18.5	14.5	17.8	17.7	17.5
Liver	5.0	4.7	8.8	8.7	8.5	8.1	8.0	7.9	3.8	3.8	3.7	7.2	7.1	7.0	7.0
Intestines	5.0	9.4	8.8	8.7	4.2	4.0	8.0	3.9	7.6	11.4	7.4	-	3.5	3.5	7.0
Pancreas	-	-	4.4	4.3	8.5	4.0	4.0	3.9	3.8	3.8	3.7	3.6	3.5	3.5	3.5
Lung	-	-	4.4	4.3	-	-	4.0	3.9	3.8	7.6	3.7	3.6	3.5	3.5	7.0
Urinary bladder	5.0	4.7	4.4	4.3	4.2	-	4.0	3.9	-	7.6	-	7.2	7.1	7.0	3.5
Kidney	5.0	4.7	-	4.3	4.2	8.1	-	7.9	7.6	7.6	3.7	3.6	7.1	7.0	3.5
Skin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Breast	-	-	4.4	4.3	-	4.0	-	3.9	3.8	3.8	3.7	3.6	3.5	3.5	3.5
Ovary	5.0	4.7	4.4	4.3	-	-	-	-	3.8	3.8	7.4	3.6	3.5	3.5	7.0
Corpus uteri	-	-	4.4	4.3	4.2	-	-	-	-	3.8	-	-	-	-	-
Cervix uteri	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	3.4

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Esophagus	17.2	24.0	30.7	27.1	30.3	24.1	23.7	23.6	33.3	29.5	25.8	25.6	25.4	25.1	28.3	24.8	21.3	17.9	18.0
Stomach	20.6	20.6	23.8	16.9	16.8	20.6	23.7	20.2	26.6	22.9	29.0	32.0	31.8	22.0	25.1	21.7	21.3	20.9	18.0
Liver	6.8	6.8	6.8	6.7	6.7	6.8	6.7	6.6	6.6	9.8	6.4	9.6	6.3	6.2	6.2	6.2	9.1	8.9	3.0
Intestines	10.3	6.8	-	6.7	6.7	6.8	6.7	10.1	6.6	9.8	9.6	12.8	9.5	6.2	12.5	9.3	12.1	11.9	12.0
Pancreas	6.8	3.4	-	6.7	3.3	3.4	3.3	6.6	-	6.4	9.6	6.4	6.3	6.2	9.4	6.2	6.0	8.9	9.0
Lung	6.8	6.8	10.2	6.7	6.7	10.3	3.3	10.1	10.0	9.8	6.4	9.6	12.7	12.5	12.5	12.4	12.1	14.9	15.5
Urinary bladder	3.4	3.4	6.8	3.3	3.3	3.4	6.7	3.3	3.3	-	3.2	6.4	6.3	9.4	6.2	3.1	6.0	5.9	9.0
Kidney	-	3.4	6.8	6.7	6.7	3.4	10.1	6.6	3.3	3.2	6.4	6.4	6.3	6.2	6.2	6.2	9.1	8.9	9.0
Skin	-	3.4	-	-	-	-	-	-	-	-	-	-	3.1	-	-	3.1	-	-	-
Breast	3.4	6.8	3.4	3.3	3.3	6.8	6.7	3.3	6.6	6.4	6.4	6.4	6.3	6.2	6.2	9.3	9.1	5.9	9.0
Ovary	3.4	3.4	6.8	6.7	3.3	3.4	3.3	3.3	6.6	3.2	3.2	6.4	6.3	6.2	6.2	6.2	6.0	5.9	6.0
Corpus uteri	3.4	-	-	-	3.3	-	-	3.3	3.3	-	-	-	3.1	3.1	-	-	3.0	2.9	3.0
Cervix uteri	3.4	3.4	-	-	3.3	3.4	3.3	3.3	-	3.2	3.2	-	-	3.1	-	3.1	-	2.9	3.0

Table C-11. Continued.

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Esophagus	17.8	18.2	22.2	21.6	18.7	27.9	18.6	18.5	21.3	19.2	19.6	16.2	12.9	21.8
Stomach	17.8	15.2	22.2	21.6	18.7	24.8	18.6	15.4	21.3	19.2	13.0	16.2	12.9	21.8
Liver	-	6.0	9.5	9.2	-	6.2	-	6.1	9.1	-	6.5	6.4	6.4	9.3
Intestines	11.9	15.2	12.6	12.3	12.5	12.4	12.4	15.4	12.1	12.8	6.5	6.4	6.4	12.5
Pancreas	5.9	9.1	6.3	6.1	6.2	9.3	6.2	9.2	-	6.4	6.5	6.4	6.4	6.2
Lung	20.7	18.2	12.6	12.3	21.8	12.4	21.8	18.5	12.1	22.4	22.8	22.7	22.5	12.5
Urinary bladder	8.9	9.1	6.3	6.1	9.3	6.2	9.3	9.2	6.0	9.6	9.8	9.7	9.6	6.2
Kidney	8.9	6.0	9.5	9.2	9.3	6.2	9.3	6.1	9.1	9.6	9.8	9.7	9.6	9.3
Skin	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Breast	8.9	9.1	9.5	9.2	9.3	6.2	9.3	9.2	9.1	9.6	9.8	9.7	9.6	9.3
Ovary	5.9	6.0	6.3	6.1	6.2	6.2	6.2	6.1	6.0	6.4	6.5	6.4	6.4	6.2
Corpus uteri	2.9	3.0	3.1	-	-	-	3.1	3.0	3.0	3.2	3.2	3.2	3.2	3.1
Cervix uteri	-	3.0	-	3.0-3.1	-	-	3.0	-	-	-	-	-	-	-

Table C-12. Dynamics of SMR and RR of lung cancer among the population of Makanchy, Urdzhar and Taskesken Districts and the control District of Kokpekty.

		1949	**1950**	**1951**	**1952**	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1959**
SMR	Makanchy	-	-	0.000047	-	-	-	0.000042	0.000041	0.00004	0.000078	0.000038
	Urdzhar, Taskesken	-	0.000026	0.000025	-	0.000025	0.000025	0.000024	0.000023	0.000022	0.000044	0.000042
	Kokpekty	-	-	0.000044	0.000043	-	-	0.000040	0.000039	0.000038	0.000076	0.000037
RR	Makanchy	-	-	1.06	-	-	-	1.05	1.05	1.05	1.02	1.02
	Urdzhar, Taskesken	-	-	0.56	-	-	-	0.6	0.58	0.57	0.57	1.13
		1960	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**
SMR	Makanchy	0.000037	0.000036	0.000071	0.000067	0.000068	0.000068	0.000101	0.000067	0.000067	0.0001	0.000033
	Urdzhar, Taskesken	0.000042	0.000020	0.000019	0.000037	0.000057	0.000057	0.000055	0.000054	0.000054	0.000053	0.000052
	Kokpekty	0.000036	0.000035	0.000035	0.000070	0.000068	0.000068	0.000102	0.000067	0.000067	0.000103	0.000033
RR	Makanchy	1.02	1.02	2.02	0.95	1.0	1.0	0.99	1.0	1.0	0.97	1.0
	Urdzhar, Taskesken	1.16	0.57	0.54	0.52	0.83	0.83	0.53	0.80	0.80	0.51	1.57
		1971	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**
SMR	Makanchy	0.000098	0.000097	0.000096	0.000064	0.000094	0.000125	0.000123	0.000121	0.000118	0.000117	0.000146
	Urdzhar, Taskesken	0.000051	0.000051	0.000051	0.000050	0.000049	0.000064	0.000047	0.000062	0.000045	0.000075	0.000074
	Kokpekty	0.000101	0.0001	0.000098	0.000064	0.000096	0.000127	0.000125	0.000125	0.000124	0.000121	0.000149
RR	Makanchy	0.97	0.97	0.97	1.0	0.97	0.98	0.98	0.96	0.95	0.96	0.97
	Urdzhar, Taskesken	0.50	0.51	0.52	0.78	0.51	0.50	0.37	0.49	0.36	0.61	0.49
		1982	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
SMR	Makanchy	0.000141	0.000196	0.000167	0.000222	0.000303	0.000357	0.000356	0.000352	0.000325	0.000431	0.000426
	Urdzhar, Taskesken	0.000072	0.000113	0.000111	0.000108	0.000131	0.000155	0.000223	0.000218	0.000239	0.000236	0.000117
	Kokpekty	0.000150	0.000208	0.000182	0.000121	0.000120	0.000218	0.000124	0.000218	0.000185	0.000121	0.000224
RR	Makanchy	0.94	0.94	0.91	1.83	2.52	1.63	2.87	1.61	1.75	3.56	1.90
	Urdzhar, Taskesken	0.48	0.54	060	0.89	1.09	0.71	1.79	1.0	1.29	1.95	0.52
		1993	**1994**	**1995**	**1996**							
SMR	Makanchy	0.000391	0.000358	0.000381	0.000354							
	Urdzhar, Taskesken	0.000117	0.000128	0.000127	0.000137							
	Kokpekty	0.000228	0.000227	0.000225	0.000125							
RR	Makanchy	1.71	1.57	1.69	2.83							
	Urdzhar, Taskesken	0.51	0.56	0.56	1.09							

Table C-13. Dynamics of SMR and RR of breast cancer among the population of Makanchy, Urdzhar and Taskesken Districts.

		1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
SMR	Makanchy	-	-	0.000047	-	-	0.000044	0.000042	0.000041	0.00004	0.000039	0.000038
	Urdzhar, Taskesken	-	0.000026	-	0.000025	0.000025	0.000025	0.000024	0.000023	0.000022	0.000022	0.000042
	Kokpekty	-	-	0.000044	0.000043	-	0.000040	-	0.000039	0.000038	0.000038	0.000037
RR	Makanchy	-	-	1.06	-	-	1.1	-	1.05	1.05	1.02	1.02
	Urdzhar, Taskesken	-	-	-	0.58	-	0.62	-	0.58	0.57	0.57	1.13
		1960	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**
SMR	Makanchy	0.000037	0.000036	0.000035	0.000033	0.000034	0.000068	0.000033	0.000033	0.000033	0.000066	0.000067
	Urdzhar, Taskesken	0.000042	0.000020	0.000019	0.000018	0.000038	0.000038	0.00037	0.000036	0.000036	0.000035	0.000034
	Kokpekty	0.000036	0.000035	0.000035	0.000035	0.000034	0.000068	0.000034	0.000033	0.000033	0.000068	0.000067
RR	Makanchy	1.02	1.02	1.0	0.94	1.0	1.0	0.97	1.0	1.0	0.97	1.0
	Urdzhar, Taskesken	1.16	0.57	0.54	0.51	1.11	0.55	1.08	1.09	1.09	0.51	0.50
		1971	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**
SMR	Makanchy	0.000032	0.000064	0.000064	0.000064	0.000063	0.000062	0.000061	0.000060	0.000088	0.000088	0.000058
	Urdzhar, Taskesken	0.000034	0.000034	0.000034	0.000033	0.000032	0.000032	0.000031	0.000031	0.000030	0.000045	0.00007
	Kokpekty	0.000033	0.000066	0.000065	0.000064	0.000064	0.000063	0.000062	0.000062	0.000093	0.000091	0.000059
RR	Makanchy	0.96	0.96	0.98	1.0	0.98	0.98	0.98	0.96	0.94	0.96	0.98
	Urdzhar, Taskesken	1.03	0.51	0.52	0.51	0.5	0.5	0.5	0.5	0.32	0.49	1.18
		1982	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
SMR	Makanchy	0.000084	0.000084	0.000083	0.000138	0.000165	0.000192	0.000191	0.000189	0.000216	0.000269	0.00024
	Urdzhar, Taskesken	0.000029	0.000056	0.000055	0.000054	0.000079	0.000103	0.000124	0.000121	0.000131	0.000130	0.000130
	Kokpekty	0.000090	0.000089	0.000091	0.000095	0.000090	0.000093	0.000062	0.000093	0.000092	0.000091	0.000096
RR	Makanchy	0.93	0.94	0.91	1.45	1.83	2.06	3.08	2.03	2.34	2.95	2.5
	Urdzhar, Taskesken	0.32	0.62	0.60	0.56	0.87	1.10	2.0	1.30	1.42	1.42	0.97
		1993	**1994**	**1995**	**1996**							
SMR	Makanchy	0.000234	0.000204	0.000229	0.000202							
	Urdzhar, Taskesken	0.000070	0.000093	0.000092	0.000202							
	Kokpekty	0.000098	0.000097	0.000096	0.000093							
RR	Makanchy	2.38	2.10	2.38	2.17							
	Urdzhar, Taskesken	0.71	0.95	0.95	0.86							

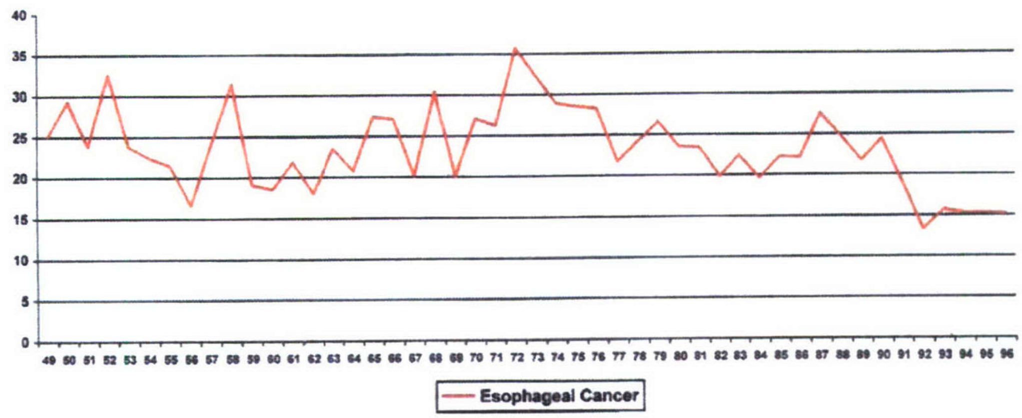

Figure C-1. Dynamics of SMR of Makanchy District population from esophageal cancer (per 100,000 persons).

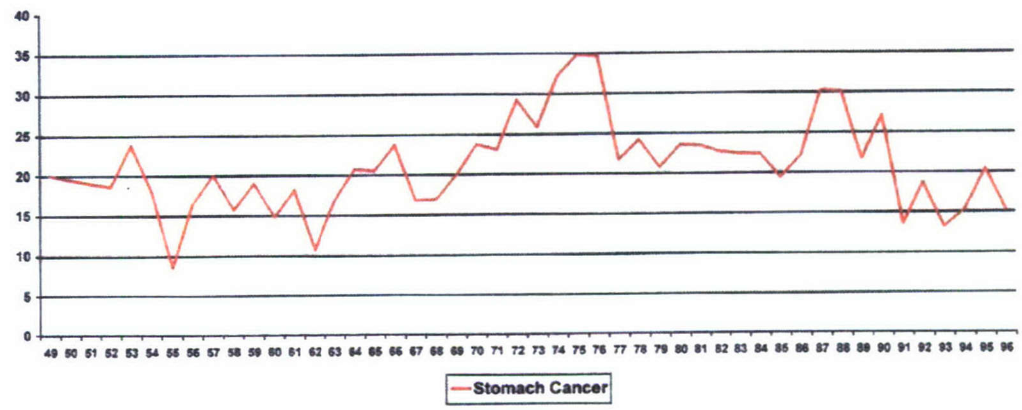

Figure C-2. Dynamics of SMR of Makanchy District population from stomach cancer (per 100,000 persons).

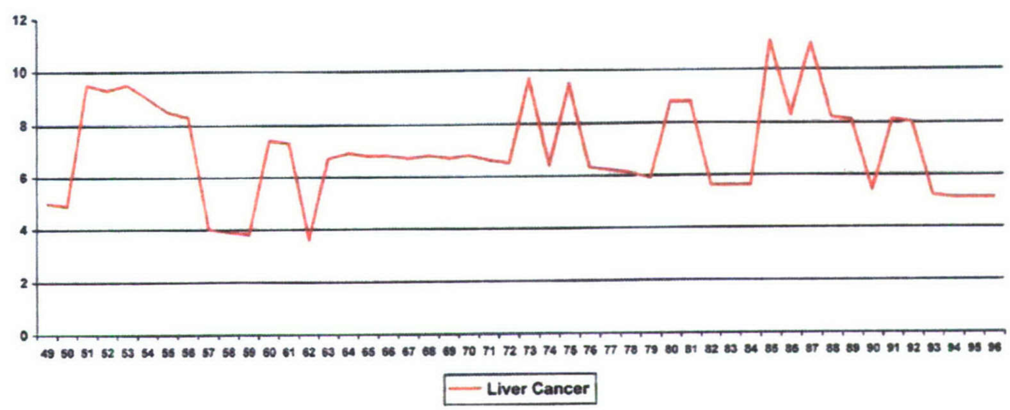

Figure C-3. Dynamics of SMR of Makanchy District population from liver cancer (per 100,000 persons).

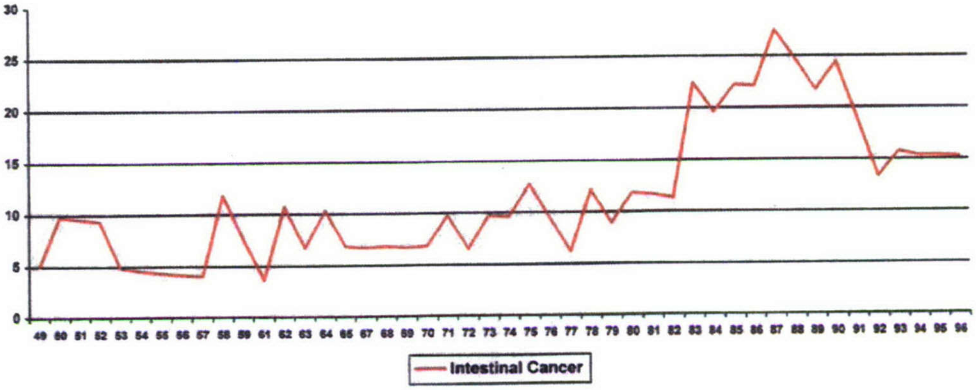

Figure C-4. Dynamics of SMR of Makanchy district population from intestinal cancer (per 100,000 persons).

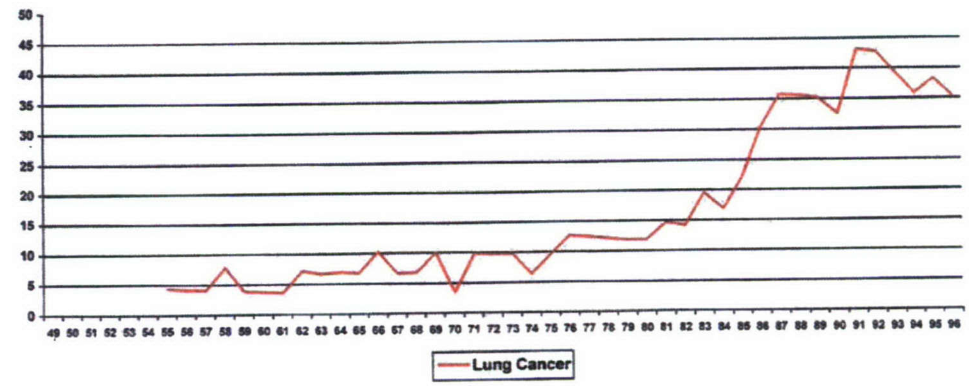

Figure C-5. Dynamics of SMR of Makanchy district population from lung cancer (per 100,000 persons).

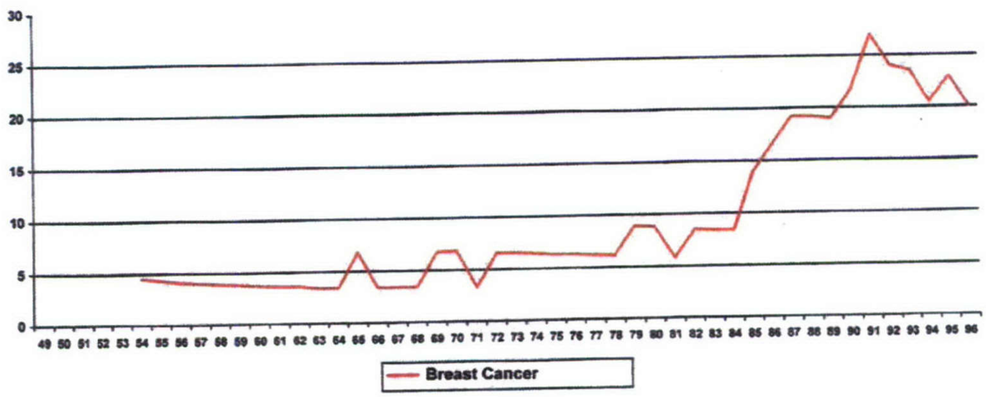

Figure C-6. Dynamics of SMR of Makanchy District population from breast cancer (per 100,000 persons).

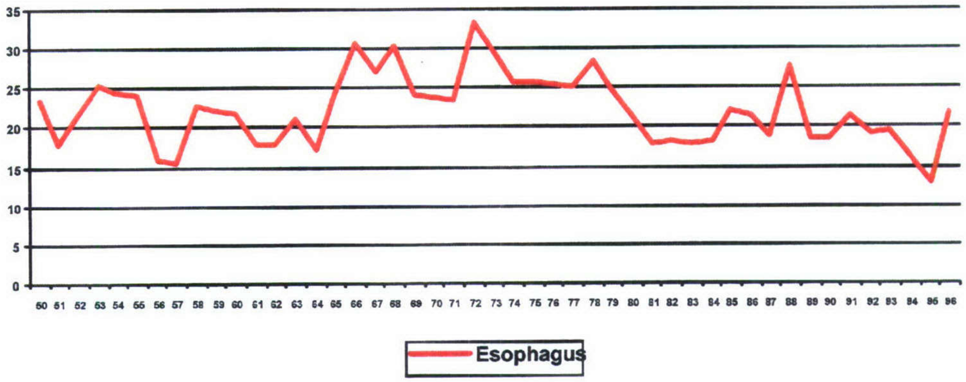

Figure C-7. Dynamics of SMR of Kokpekty District population from esophageal cancer (per 100,000 people).

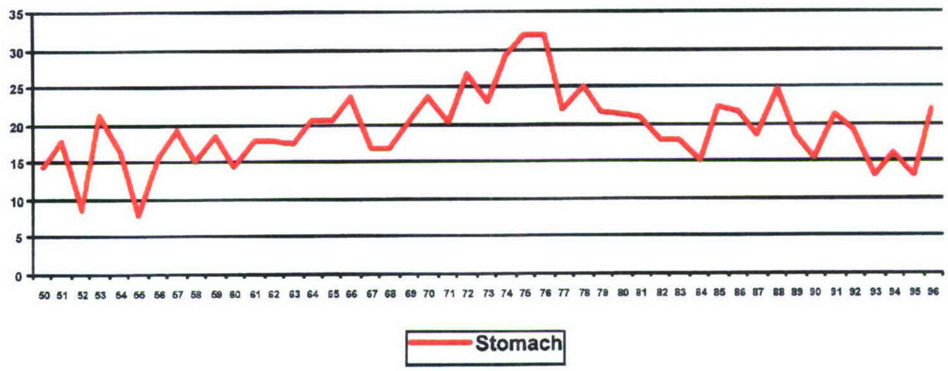

Figure C-8. Dynamics of SMR of Kokpekty District population from stomach cancer (per 100,000 people).

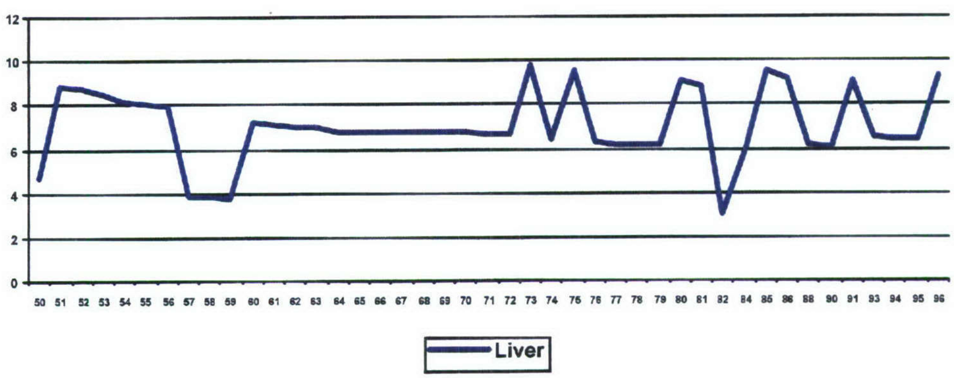

Figure C-9. Dynamics of SMR of Kokpekty District population from liver cancer (per 100,000 people).

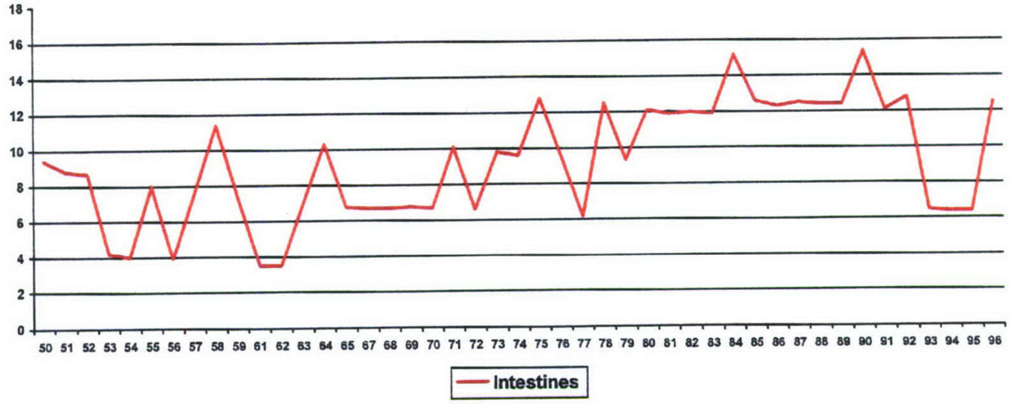

Figure C-10. Dynamics of SMR of Kokpekty District population from intestinal cancer.

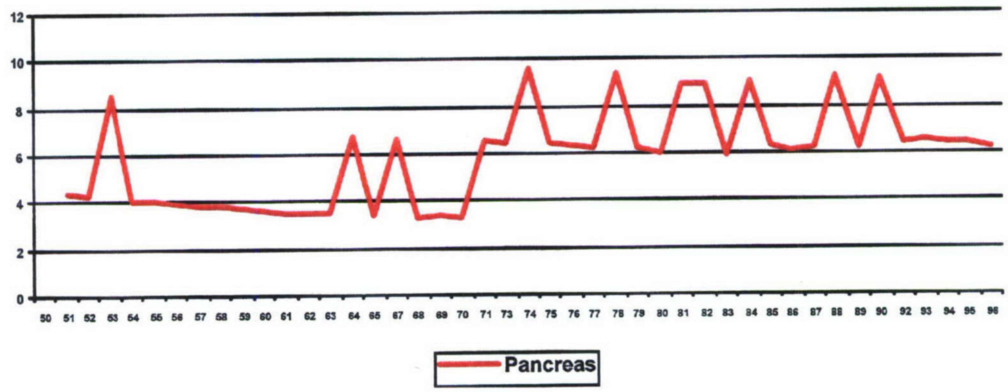

Figure C-11. Dynamics of SMR of Kokpekty District population from pancreatic cancer (per 100,000 people).

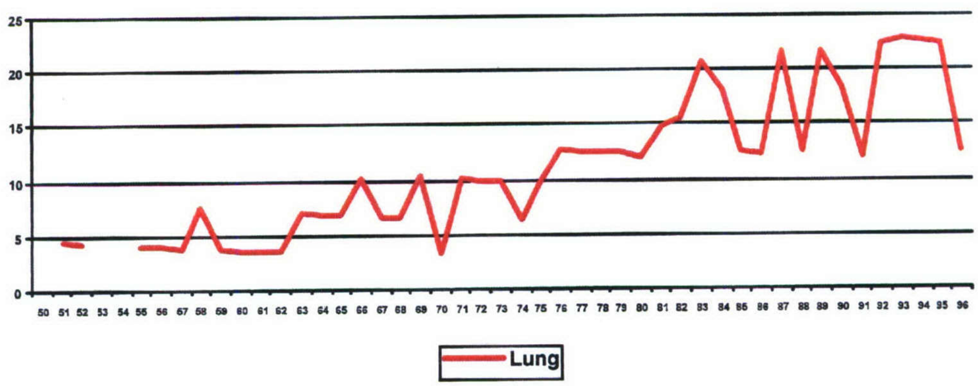

Figure C-12. Dynamics of SMR of Kokpekty District population from lung cancer (per 100,000 people).

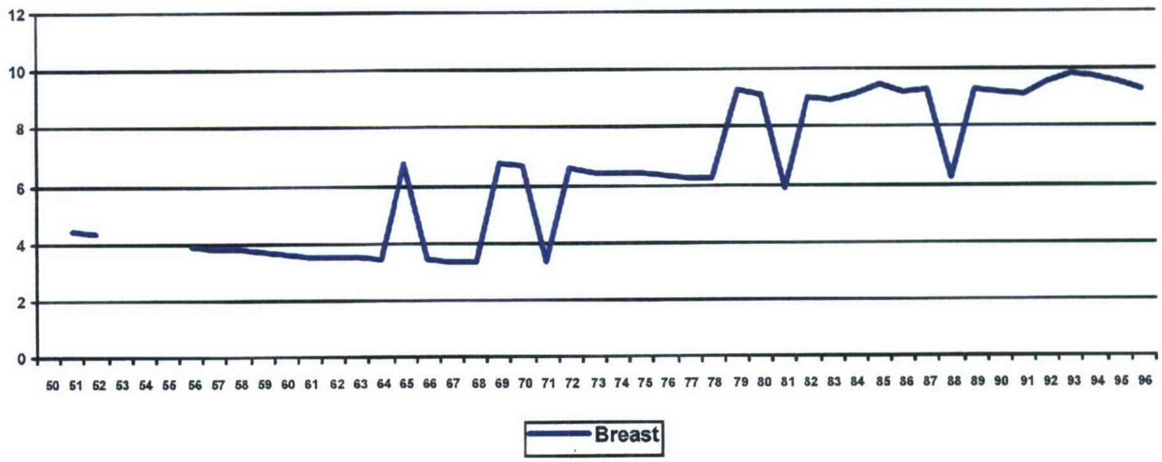

Figure C-13. Dynamics of SMR of Kokpekty District population from breast cancer (per 100,000 people)

APPENDIX D

Spectrometry Graphs

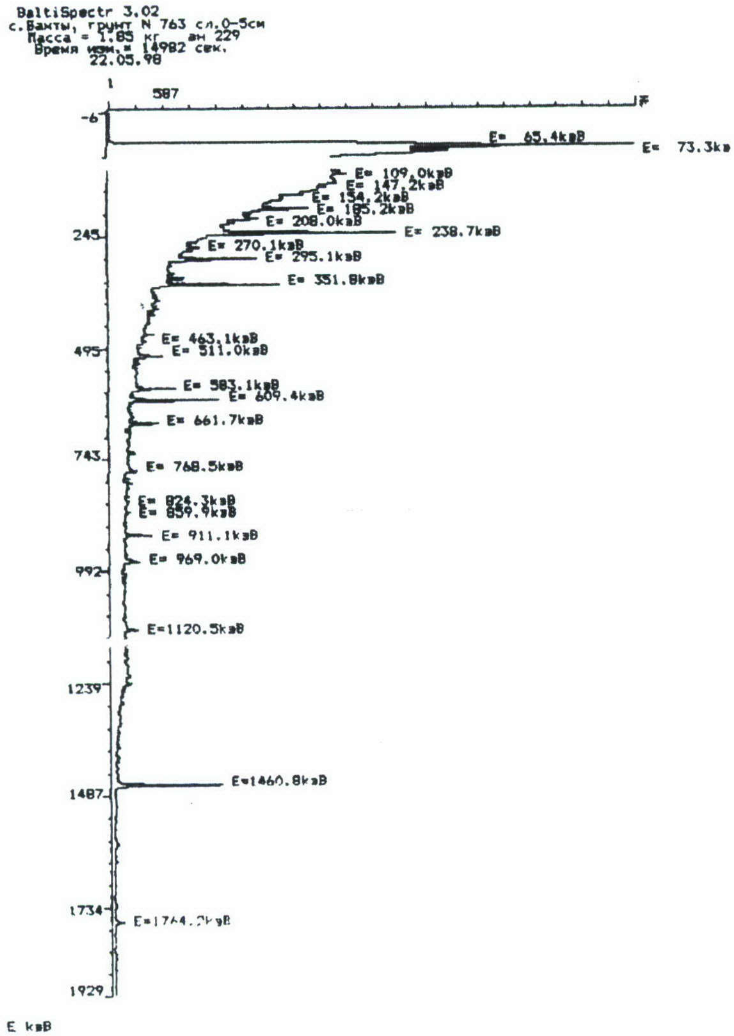

Figure D-1. Spectrograph of Soil Sample from Bakhty.

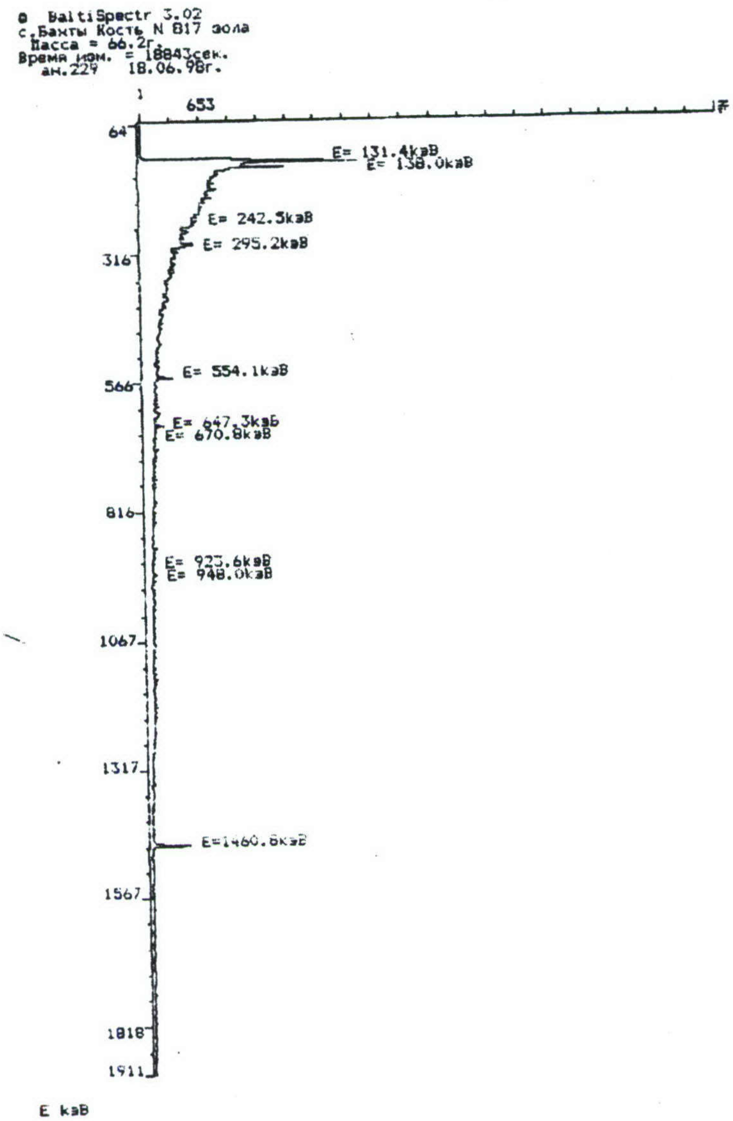

Figure D-2. Spectrograph of Bone Sample from Bakhty.

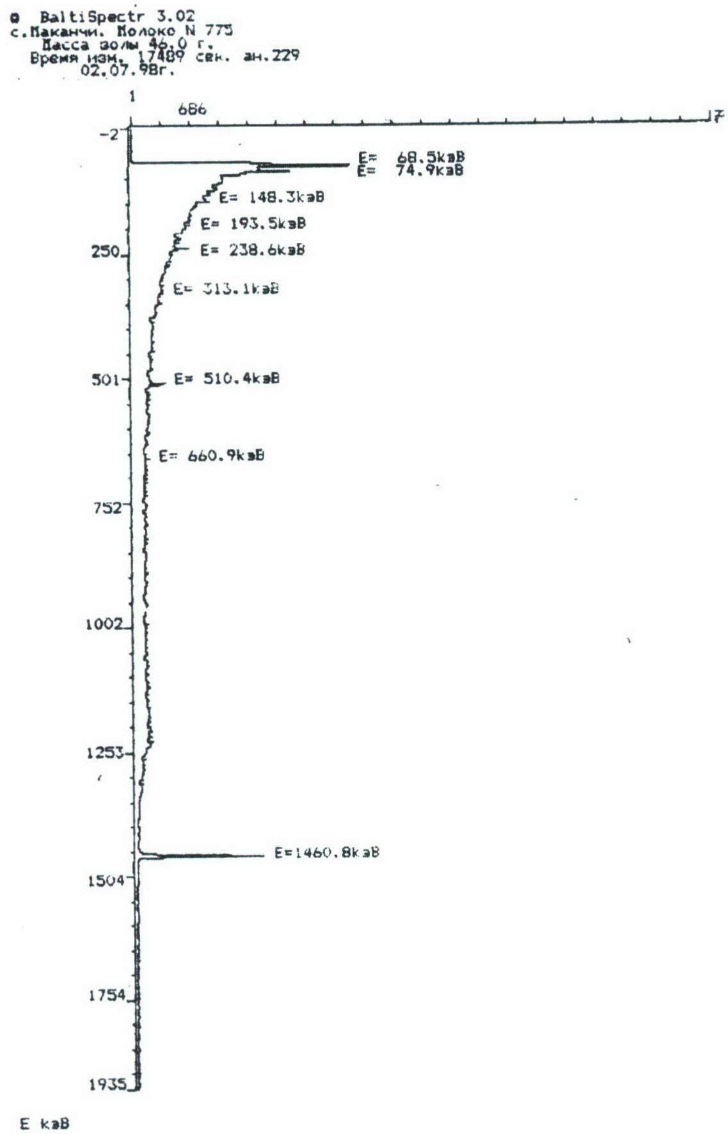

Figure D-3. Spectrograph of Milk Sample from Makanchy.

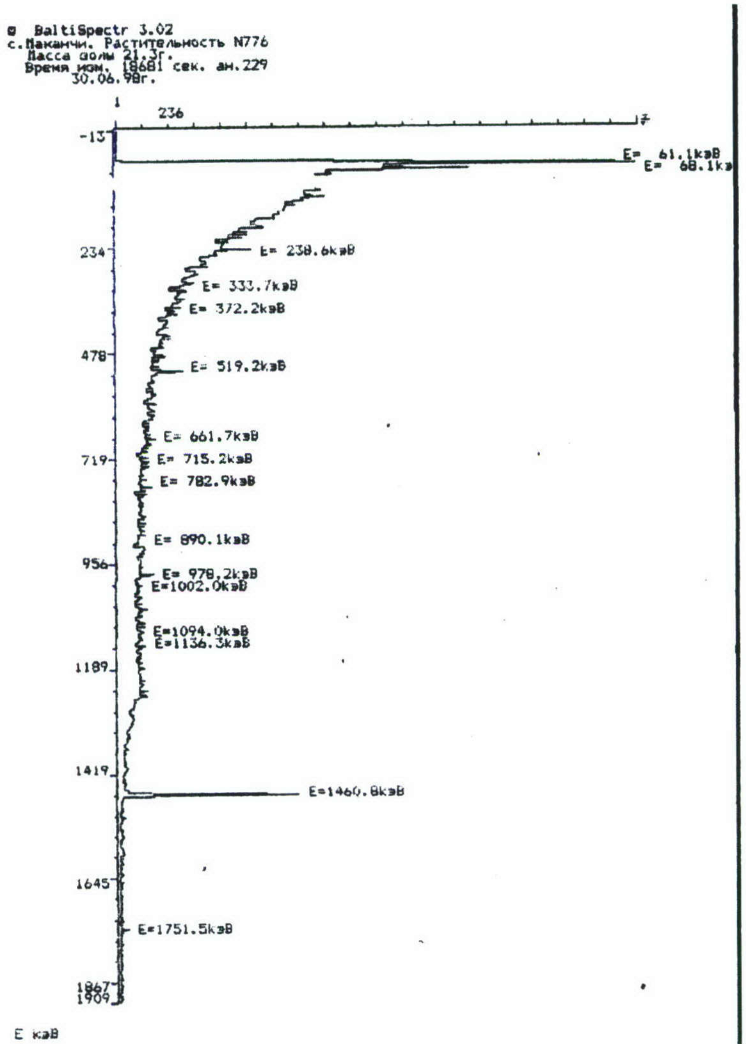

Figure D-4. Spectrograph of Vegetation Sample from Makanchy.

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